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MINI-RPV COMMUNICATION JAMMER DEMONSTRATION PROGRAM. (U)

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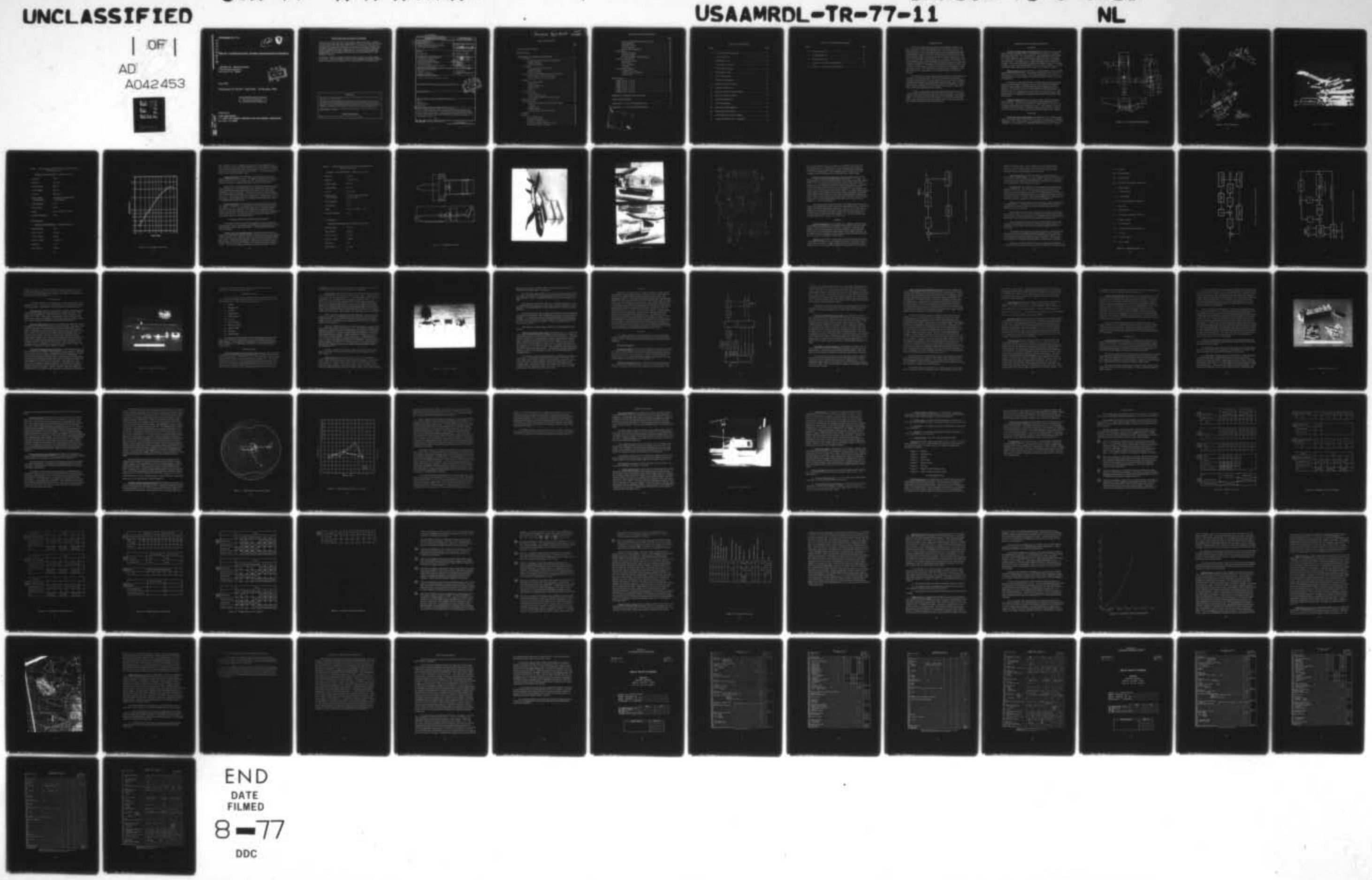

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MINI-RPV COMMUNICATION JAMMER DEMONSTRATION PROGRAM

E-SYSTEMS INC., MELPAR DIVISION
7700 Arlington Boulevard
Falls Church, Va. 22046

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June 1977

Final Report for Period 7 April 1976 - 31 December 1976

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Prepared for

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
Fort Eustis, Va. 23604

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EUSTIS DIRECTORATE POSITION STATEMENT

This report shows that a low power communications jammer, carried by a mini-RPV, is a feasible means of jamming enemy communications. The lack of detailed data precludes an exact determination of the effectiveness or range of such jammers. The results of this flight test program will be integrated with the results of the Army's AQUILA RPV Systems Technology Demonstrator Program and the Air Force's mini-RPV harassment program to determine the military requirements for a communications jamming system using mini-RPVs. This determination will be made by the newly formed U.S. Army Intelligence Command.

Mr. Russell O. Stanton of the Systems Support Division served as the project engineer for this effort. CPT Tom Vollrath of the U. S. Army Intelligence and Security Command served as an assistant project engineer for the jammer portion of the technical effort.

DISCLAIMERS

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

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This is the final report of a program to demonstrate the utility of deploying a low power, communication jammer on a mini remotely piloted vehicle (RPV) operating beyond the line of contact (LOC). The effectiveness of the airborne jammers against ground communications links was demonstrated during flight tests conducted at Fort Huachuca, Arizona.

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INTRODUCTION

The utility of deploying a low power communications jammer on an RPV was demonstrated during flight tests at Fort Huachuca, Arizona. Two different jammers were used during the tests: a narrow band jammer and a barrage jammer. The narrow band (spot) jammer was designed and fabricated under this contract, while the barrage jammer was furnished by Army Security Agency (ASA). The spot jammer has a frequency range of 30 to 76 MHz at a power output level of either 25, 10, or 5 watts. The jammer is FM noise modulated with a frequency dispersion variable from 3 to 200 kHz. The frequency and dispersion are controlled from the ground and were operated in a "hands on" mode; i.e., the signal to be jammed was selected by the ground controller, and the jammer frequency and dispersion were adjusted for optimum power density. The ASA barrage jammer was used essentially "as is" (the modules were repackaged so as to be interchangeable with the spot jammer).

The jammers were mounted in two different RPV's for the flight tests: the Melpar E-45 and the E-100. The E-45 was supplied as government-furnished equipment (GFE) from a previous effort and required only minimal refurbishment in addition to the installation of the jammer. The E-100 was purchased from Melpar and required fairly extensive modifications, including the addition of autopilot control, alternator-power supply, Vega control link, as well as the installation of the jammer.

The RPV's and jammers were controlled from the ground via an RF control system manufactured by Vega Precision Laboratories. The system includes a full duplex communication link, tracking capability, and a position plotter. The ground controllers were located in a van which contained the RPV control panel, the jammer control panel, and the Vega tracking system. The control van and Vega system were also GFE.

DESCRIPTION OF PROGRAM COMPONENTS

E-45 RPV

Aircraft Characteristics and Construction—The Melpar E-45 is a single-engine, twin-boom, pusher, RPV. The tail booms are made of 2" diameter fiberglass tubing with a 1/32" wall thickness. The wing panels, and horizontal and vertical stabilizers, are constructed of a lightweight Styrene foam inner core wrapped with a laminate of a 1/8" high density foam and a two-ply fiberglass cloth skin. The wing includes a tubular fiberglass spar for additional strength. The outline drawing and construction technique of the E-45 are shown in Figures 1 and 2, and a photograph of the E-45 is shown in Figure 3. Aircraft specifications and performance typical for the E-45 are shown in Table 1.

Engine/Alternator—The E-45 utilizes a single-cylinder, two-cycle engine manufactured by Olson and Rice. The engine burns gasoline and, with a displacement of 2.0 cu. in., produces 2 hp. (See engine power curve, Figure 4.) The propeller used on this engine is two bladed, 18 inches in diameter, and has a 9-inch pitch.

The dc power required by the RPV is generated by an alternator driven directly from the engine. The Hanson Energy (model HSA-8100) alternator generates approximately 85 watts of power at speeds ranging from 3000 to 8000 rpm. The alternator has four output windings and a field winding producing 15 Vac at 2.5 A, 15 Vac at 2.5 A, 5 Vac at 1 A, and 5 Vac at 2 A. The output voltages are maintained at a constant level over the entire speed range through the use of a feedback arrangement which controls the magnitude of the field current.

Controls/Actuators—The E-45 controls consist of throttle, elevator, and twin rudders. The controls are activated by Kraft (model KPS-15 II H) position servos. The servos operate from a voltage source of +4.8 Vdc at 750 mA (max.) and produce a static torque of 38 in. oz. The position of the servo is determined by the width of a control pulse (the control pulse has a range of 1.0 ms to 1.8 ms, at a 50-Hz repetition rate) which produces a 100° rotation.

E-100 RPV

Construction and Characteristics—The Melpar E-100 is a single-engine, twin-boom, pusher, RPV. The tail booms are made of 2" diameter fiberglass tubing with a 1/32" wall thickness. The wing panels, and horizontal and vertical stabilizers, are constructed of a lightweight Styrene foam inner core wrapped

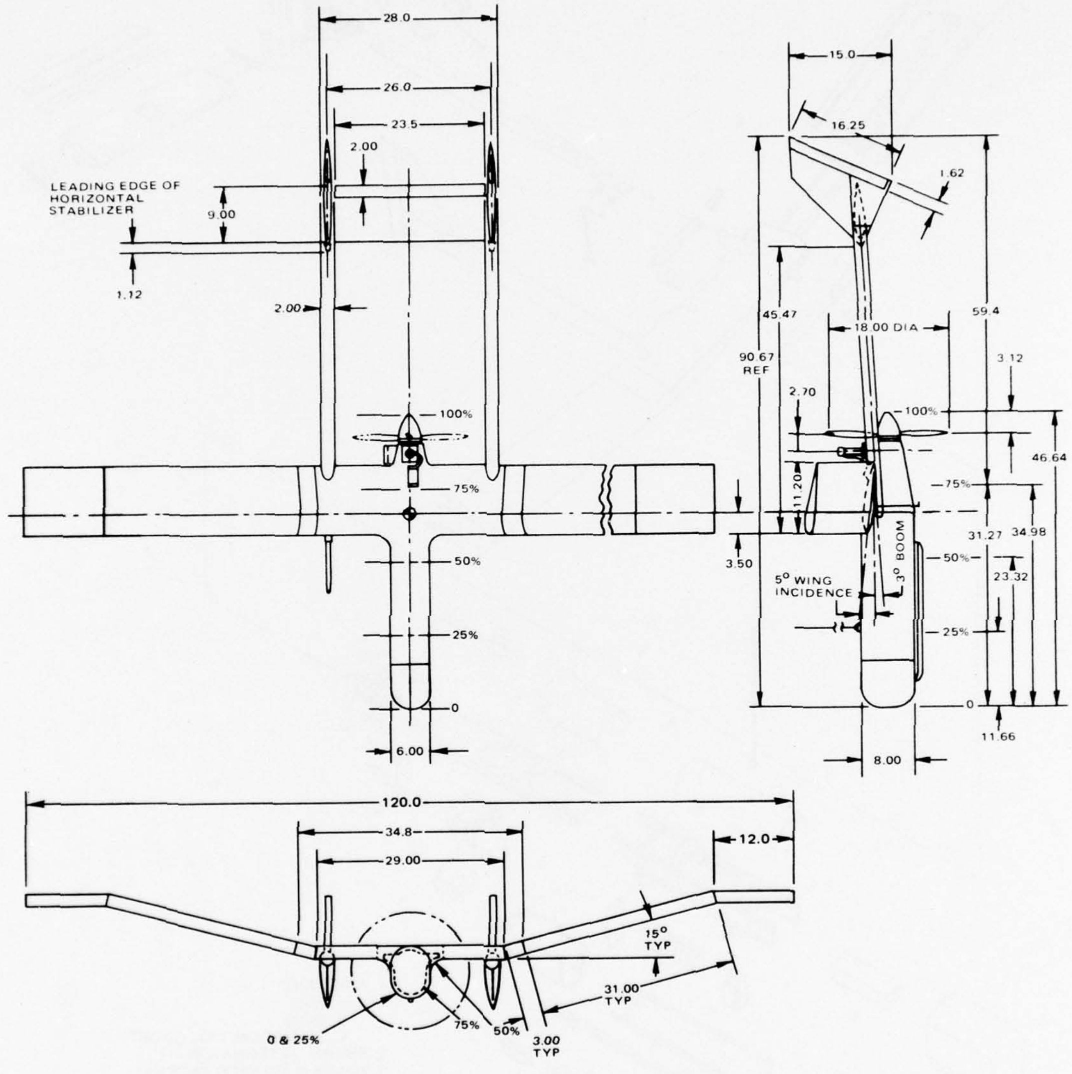

Figure 1. E-45 Aircraft Outline Drawing

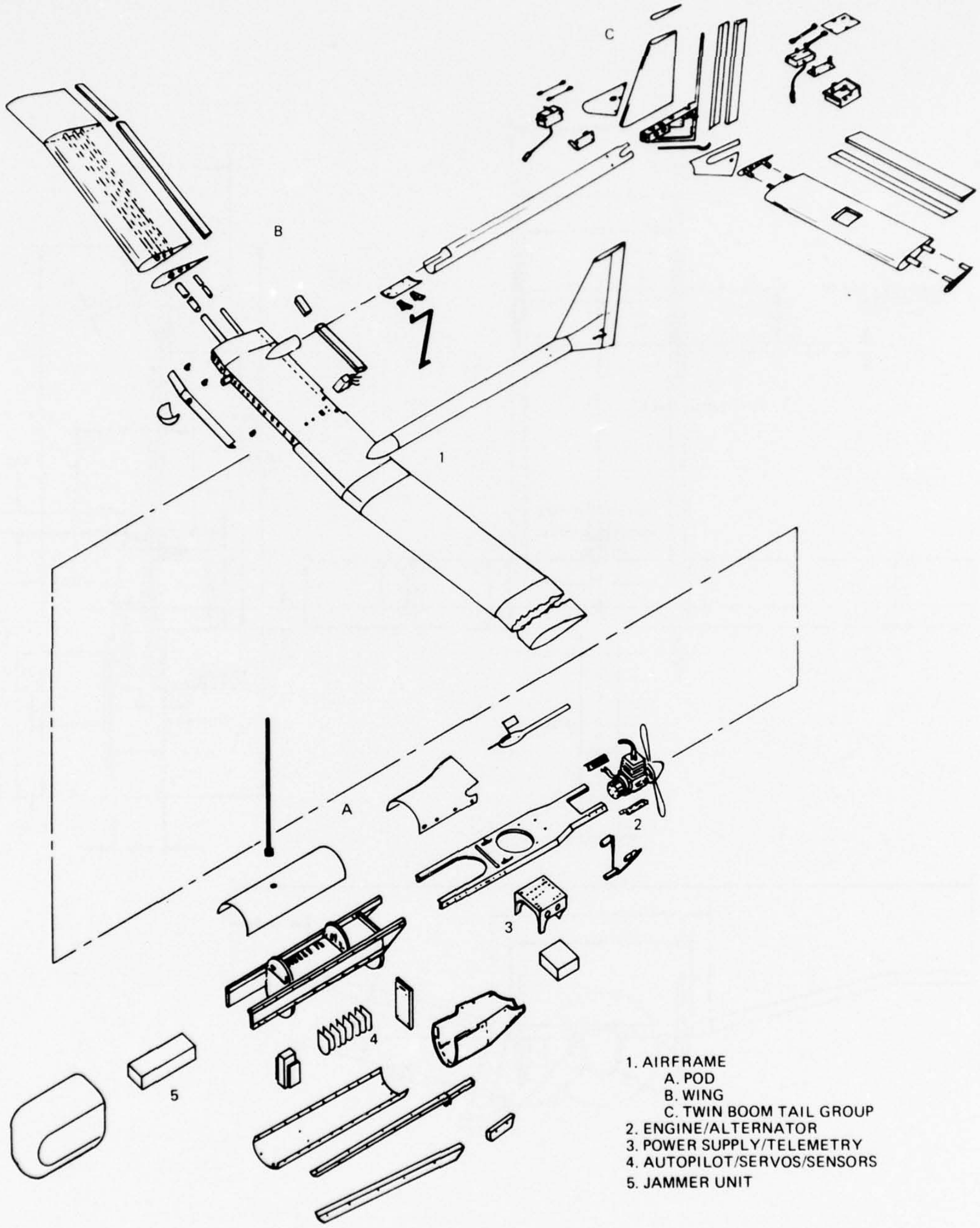

Figure 2. E-45 Construction

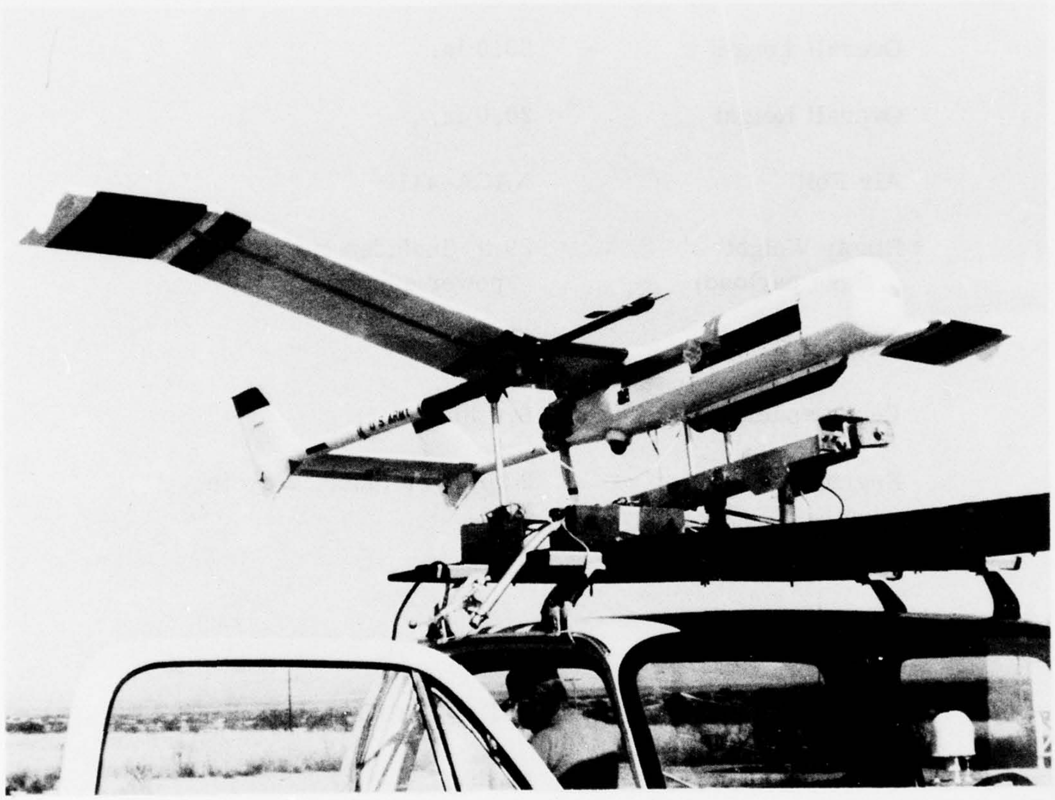

Figure 3. Photograph of E-45

TABLE 1. AIRCRAFT SPECIFICATIONS AND PERFORMANCE TYPICAL FOR E-45

AIRCRAFT SPECIFICATIONS - TYPICAL FOR E-45

Wing Span	120 in.
Wing Area	1344 sq in.
Overall Length	93.0 in.
Overall Height	20.0 in.
Air Foil	NACA-4415
* Empty Weight (less payload)	29 lb (includes autopilot and power supply)
Payload Weight	10 lb
Fuel Capacity	6.0 lb
Engine	2 hp, 1 cylinder, 2 cycle
Propeller Diameter	18 in.

*See Appendix A

AIRCRAFT PERFORMANCE - TYPICAL FOR E-45

Takeoff Weight	45 lb
Rate of Climb	750 fpm
Cruise Velocity	50 mph
Service Ceiling	10,000 feet
Endurance	5 hr
Stall Velocity	40 mph

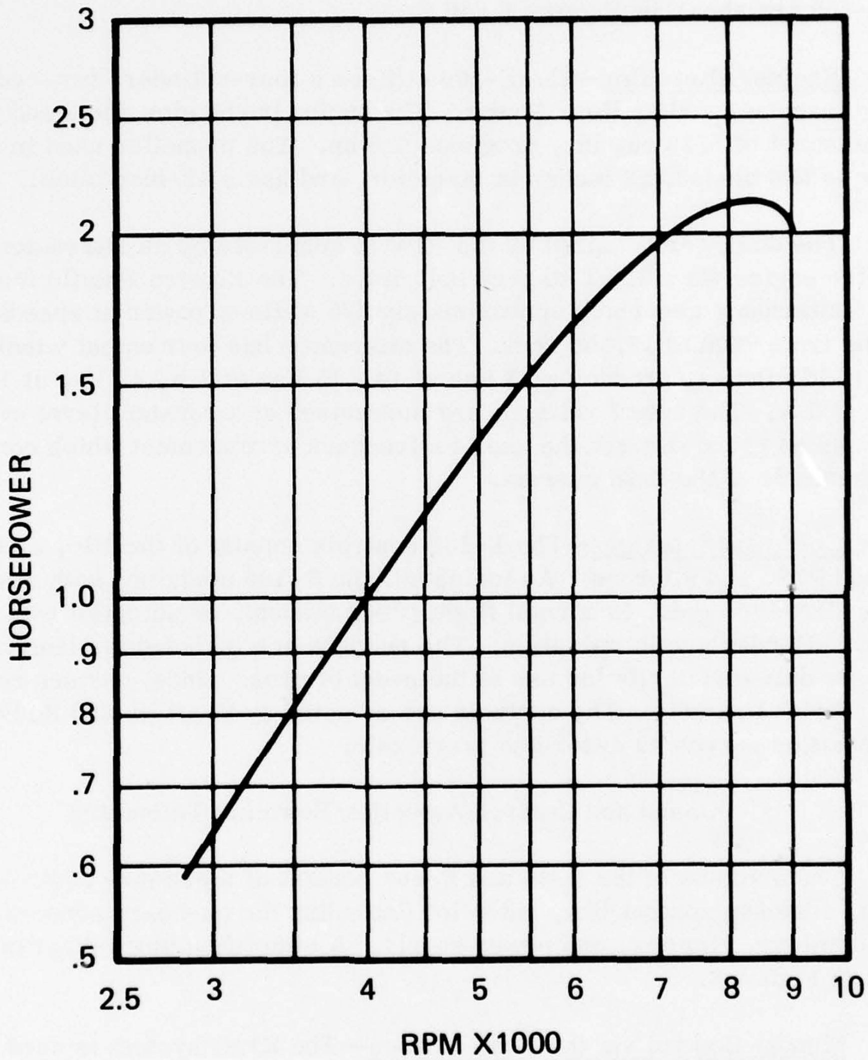

Figure 4. E-45 Engine Power Curve

with a laminate of a 1/8", high density foam and a two-ply fiberglass cloth skin. The wing includes two tubular fiberglass spars for additional strength. The specifications and performance characteristics of the E-100 are shown in Table 2, and an outline drawing is shown in Figure 5. Actual photographs of the E-100 are shown in Figures 6 and 7.

Engine/Alternator—The E-100 utilizes a four-cylinder, two-cycle engine manufactured by Ross Power. The engine burns glow fuel, and with a displacement of 5.25 cu. in., produces 6.5 hp. The propeller used in this engine is two bladed, 22 inches in diameter, and has a 12-inch pitch.

The dc power required by the RPV is generated by an alternator driven from the engine via a 2.5:1 step-up belt drive. The Electro Pacific model 1-1220 alternator generates approximately 225 watts of power at speeds ranging from 7500 to 17,500 rpm. The alternator has four output windings and a field winding, producing 28 Vac at 4A, 15 Vac at 2 A, 15 Vac at 1A, and 5 Vac at 3 A. The output voltages are maintained at a constant level over the entire speed range through the use of a feedback arrangement which controls the magnitude of the field current.

Controls/Actuators—The E-100 controls consist of throttle, elevator, twin rudders, and ailerons. As indicated, the E-100 contained both ailerons and rudders; however, in normal flight (Vega manual, or autopilot control) only the ailerons are in operation. The rudders are included for landing purposes only (primarily for use in the event of cross winds) and are controlled via the Kraft link only. The controls are actuated by Kraft (model KPS-15 II H) position servos as described previously.

Command and Control/Autopilot/Downlink Telemetry

The avionics of the E-45 and E-100 consist of a primary control link (Vega), a backup control link, autopilot (including the on-board sensors), downlink telemetry, jammer, and power supply. A simplified block diagram is shown in Figure 8.

Manual Control via the Kraft System—The Kraft system is used as a backup to the Vega system and as a fail-safe control mode in the event of power failure aboard the RPV. The latter utilizes an on-board battery which supplies power only to the Kraft-related circuitry. Manual control of the RPV via the Kraft system is achieved by applying the output pulses of the Kraft receiver/decoder directly to the control actuators via mode (Kraft/Vega) switching circuitry. The mode switching is controlled by either of two events: loss of

TABLE 2. AIRCRAFT SPECIFICATIONS AND PERFORMANCE TYPICAL FOR E-100

AIRCRAFT SPECIFICATIONS - TYPICAL FOR E-100

Wing Span	129.0 in.
Wing Area	2,064.00 sq. in.
Overall Length	108.0 in.
Overall Height	22.5 in.
Air Foil	NACA-4415
* Empty Weight (less payload)	50 lb (includes autopilot and power supply)
Payload Weight	52 lb
Fuel Capacity	18 lb
Engine	6.5 hp, 4 cylinder, 2 cycle
Propeller Diameter	22 in.

* See Appendix B

AIRCRAFT PERFORMANCE - TYPICAL FOR E-100

Takeoff Weight	110 lb
Rate of Climb	750 fpm
Cruise Velocity	75 mph
Service Ceiling	5,000 ft
Endurance	5 hr
Stall Velocity	48 mph

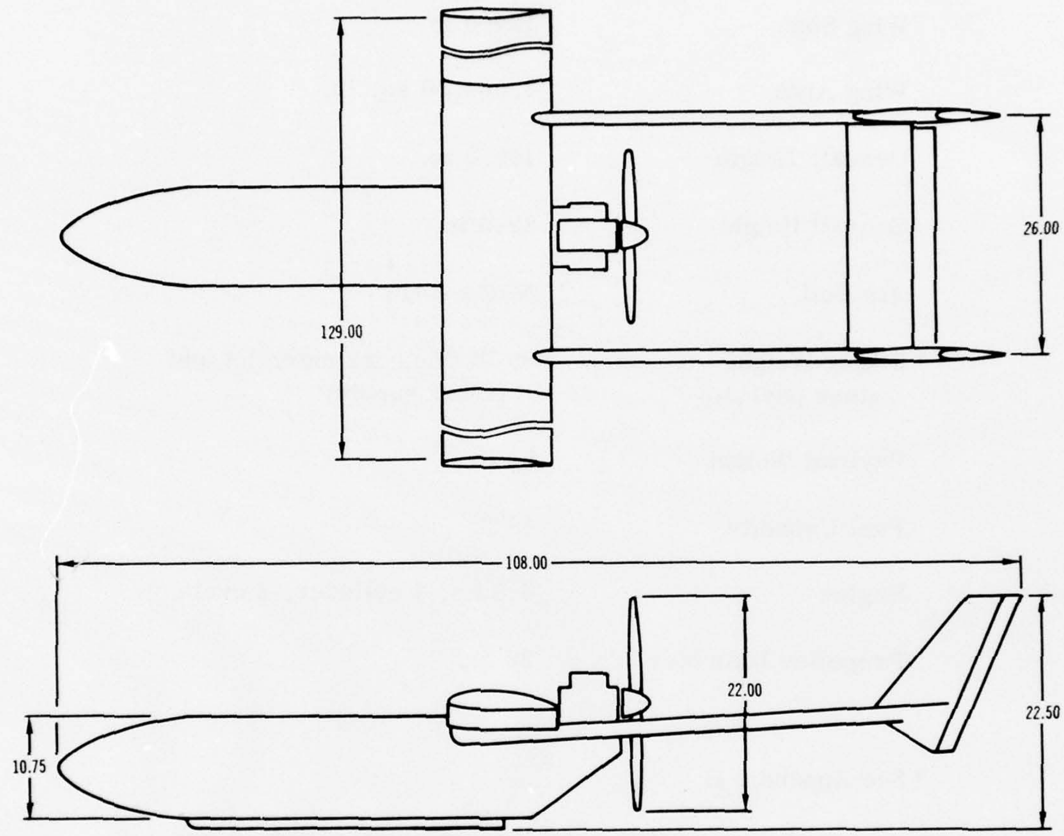

Figure 5. E-100 Outline Drawing

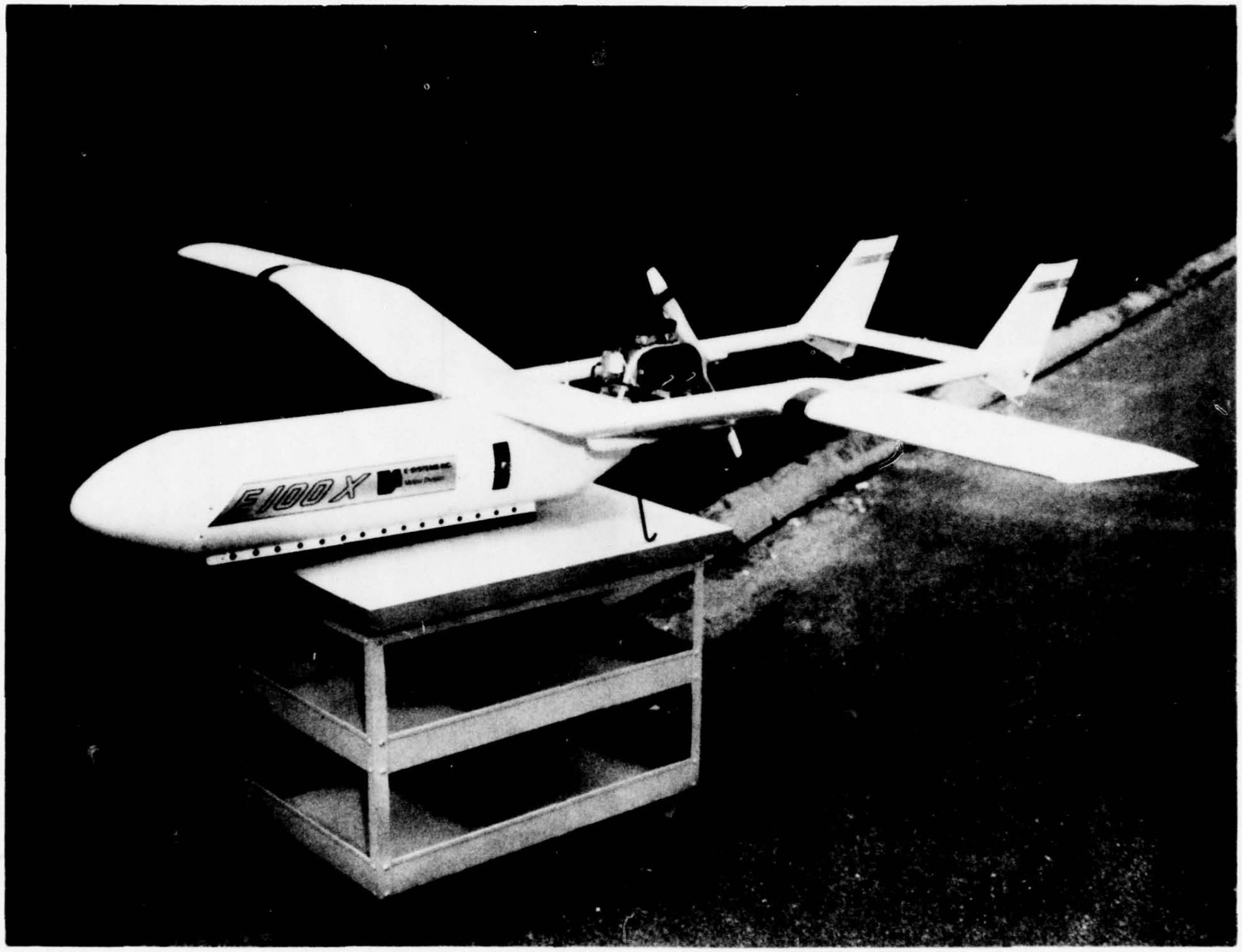

Figure 6. Photograph of E-100

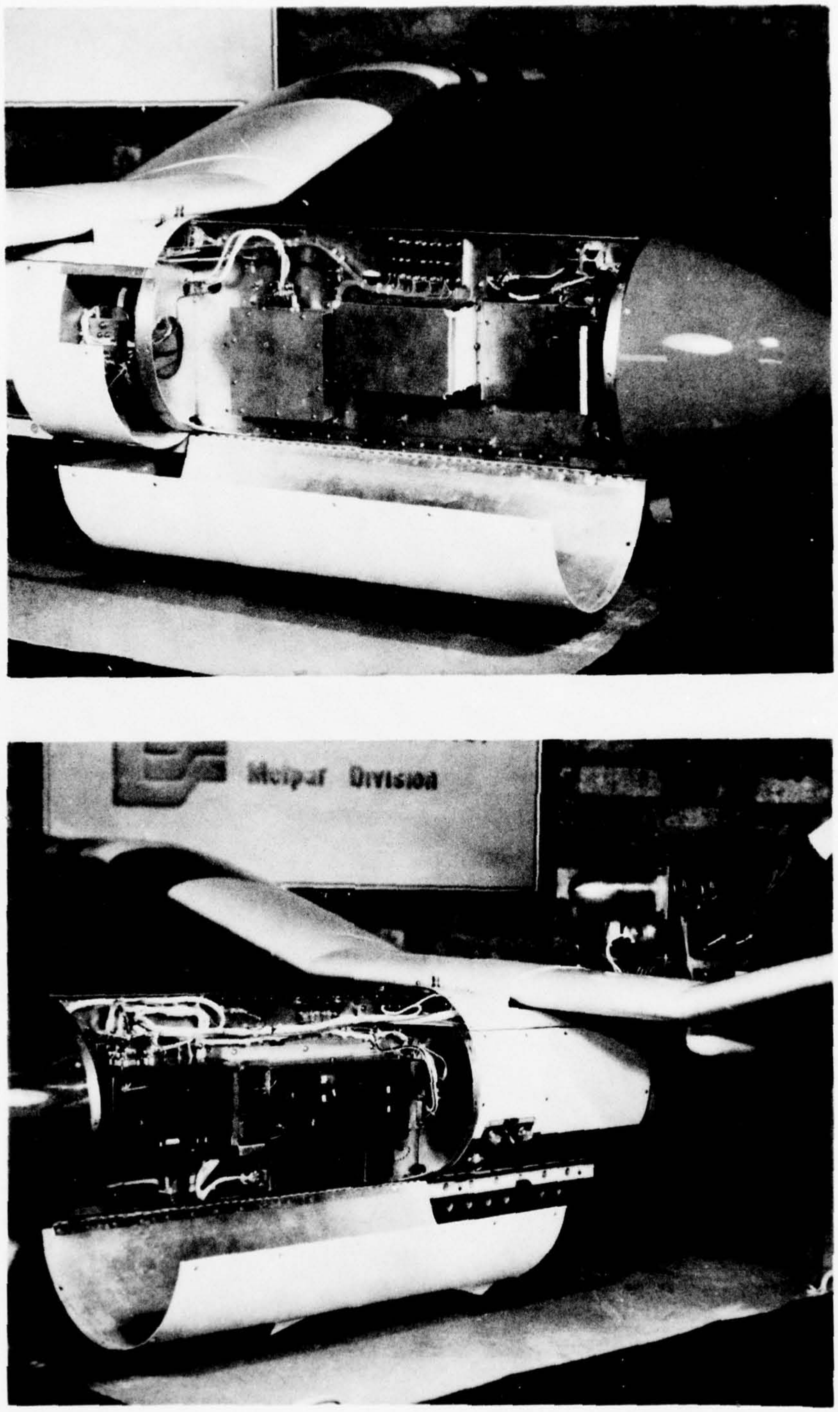

Figure 7. E-100 Construction

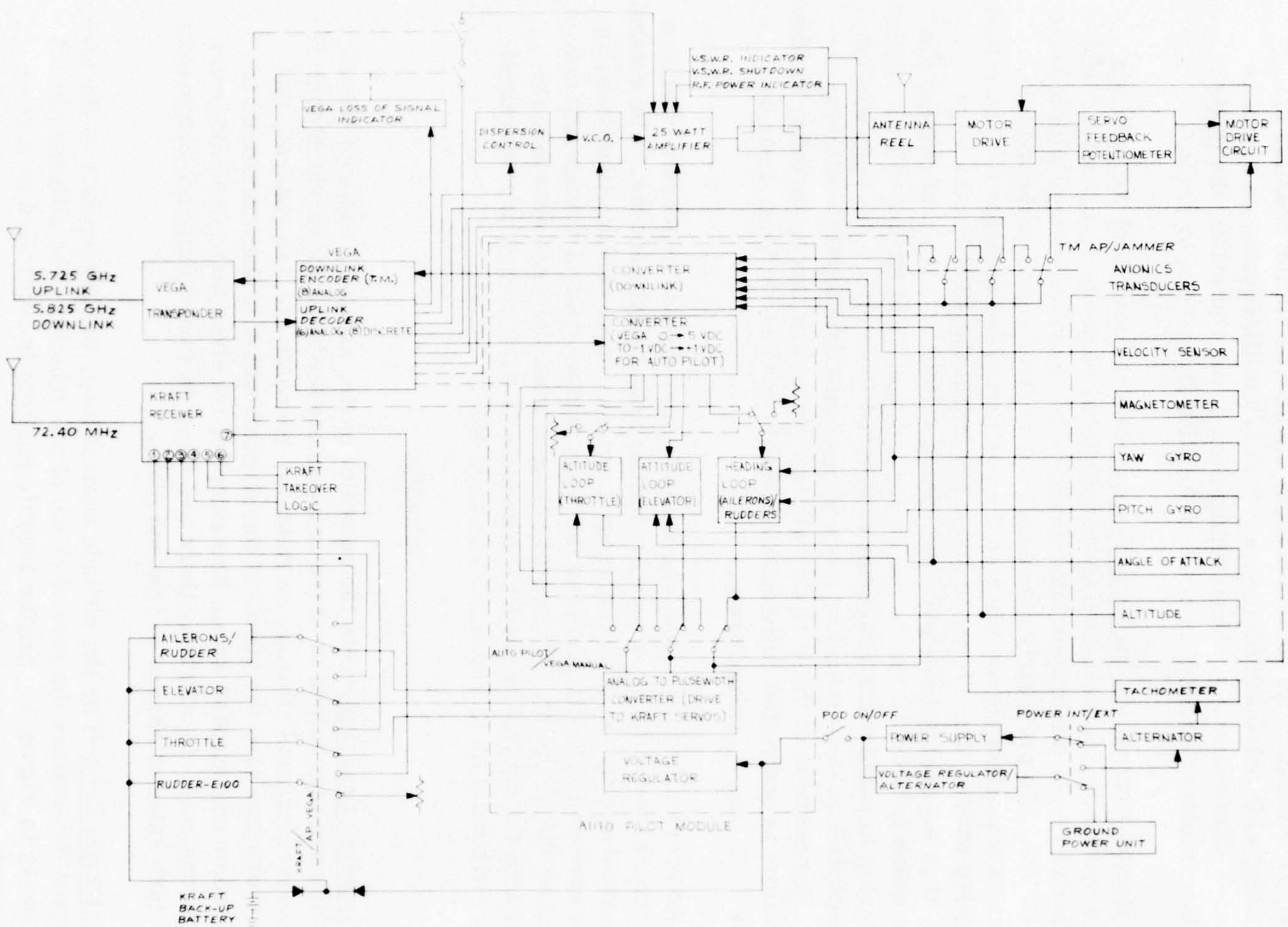

Figure 8. Avionics Block Diagram

power as denoted by the loss of +15 Vdc, or a command received from the Kraft ground station. The command from the ground station consists of transmitting wide pulse widths (greater than 1.8 milliseconds) on channels 5, 6, and 7 simultaneously. Upon recognition of the command, the mode switching circuitry transfers control of the RPV from Vega to Kraft.

Manual Control via the Vega System—Manual control of the RPV via the Vega system is achieved through proportional channels 1, 5, and 6. The signal derived from the proportional channels is an analog voltage with a range of 0 to +5 Vdc. As previously discussed, the control signal to the avionic actuators is a train of pulses wherein the position of the actuator is determined by the pulse width. Therefore, in order to control the RPV via the Vega system, it is necessary to convert the analog voltage to a train of pulses, the width of which is proportional to the analog voltage. The analog voltage applied to the analog to pulse width converter is derived from either the Vega system or the autopilot as determined by mode (Vega manual/autopilot) switching circuitry. The position of these mode switches (there are three: throttle, rudder and elevator) is controlled individually from the ground via Vega discrete channels 1, 2, and 3, respectively.

As previously mentioned, the analog to pulse width converter is driven either from the autopilot or directly from the Vega uplink decoder. The control voltages produced by the autopilot range from -1 Vdc to +1 Vdc; therefore, in order to have compatibility between the Vega manual control voltage and that produced by the autopilot, the control voltages from the Vega channels associated with the control of the RPV (channels 1, 4, 5, and 6) are converted from the original 0 to +5 Vdc to -1 Vdc to +1 Vdc.

Autopilot

General Description—In the autopilot mode, altitude, angle-of-attack, and heading are maintained by three independent feedback loops which control throttle, elevator, and ailerons or rudders, respectively. In general, the flight sensors measure the status of the aircraft which is then compared to the desired or commanded status (the autopilot receives these commands via the uplink control). In addition, there are fixed on-board (implied) commands such as zero rates of change in yaw and pitch.

Altitude Loop—For the altitude control loop, the horsepower of the aircraft engine determines the rate of climb of the vehicle. The altitude control loop is shown in Figure 9. Engine throttle position is controlled by a given altitude error. It is assumed that a change in horsepower is proportional to a

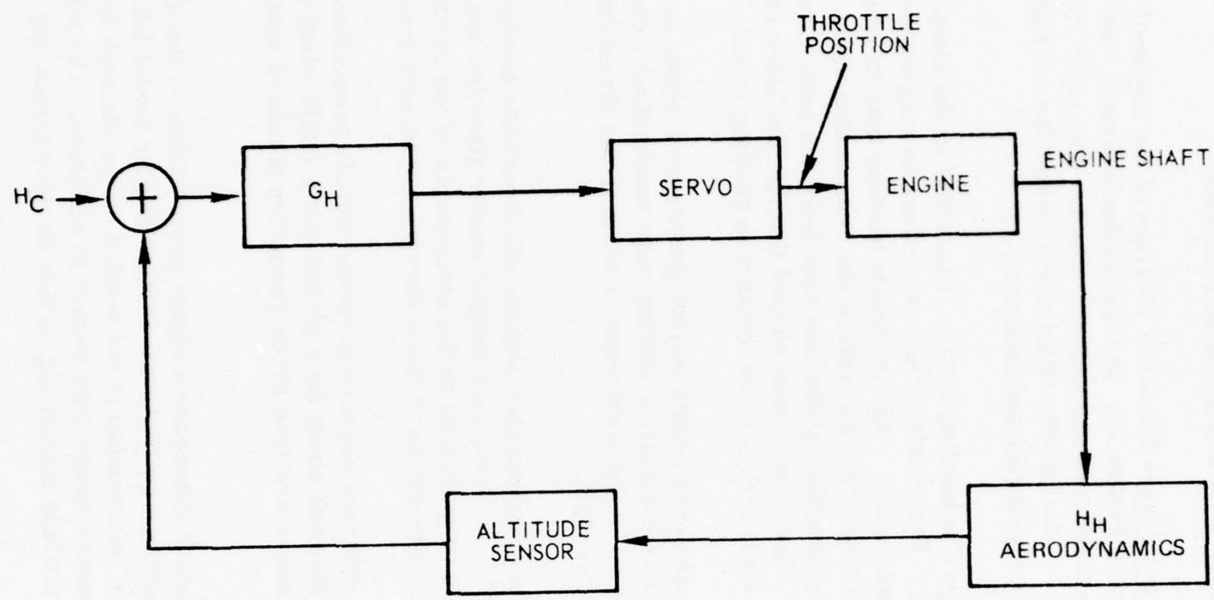

Figure 9. Altitude Loop Block Diagram

change in throttle position. Thus, altitude errors control horsepower directly. The value of G_H (A list of symbols is shown in Figure 10) is determined by the characteristics of the aircraft, its controls, and the allowable altitude error band which can be tolerated.

Angle-of-Attack Loop—The block diagram of the angle-of-attack control loop is shown in Figure 11. In this feedback circuit, the elevator rate is controlled by both pitch rate and angle of attack. The pitch rate feedback provides short-term inertial pitch stabilization, while the average value of α is maintained by the commanded and measured α.

Heading Loop—The heading loop is illustrated in the simplified block diagram of Figure 12. For clarity, the corrections in magnetometer error induced by roll are not shown. The automatic heading control aligns the average magnetic heading of the aircraft to the commanded value. Short-term stabilization in yaw is obtained by the yaw rate feedback path which provides the proper damping. Yaw rate is also passed through the lossy integrator and provides short-term (relative to $T_)$) correction in heading error.

Sensors—The angle-of-attack sensor generates a signal proportional to the angle of attack. It is basically a moving vane mechanically coupled to a potentiometer and placed in the airstream to monitor the direction of the velocity vector of the aircraft.

The heading sensor generates signals which provide heading deviation from magnetic north. It is a two-axis magnetometer (Develco model 9100A) that generates voltages proportional to the components of the earth's magnetic field in the x and y axis directions of the aircraft's coordinate system.

The yaw and pitch rate sensors generate signals proportional to the rotational rate of the aircraft about its z (down) and y (right wing) axes, respectively. These sensors are rate gyros (Hamilton Standard model 10-05414-005).

The altitude sensor generates a signal proportional to the altitude and is a barometric pressure gauge (National Semiconductor model LX1601A). Since precision altitude information is not needed on the aircraft for normal AP operation, the pressure gauge type sensor is adequate. The inherent errors of this type of altitude measuring device do not present any problem.

Magnitude of aircraft velocity is not used or needed by the autopilot. It is sensed and used primarily for the aircraft status display in the ground control

H = altitude

G_H = H feedback gain

H_C = H commanded

H_H = aircraft aerodynamics related to H

α = angle of attack

G_α = α feedback gain

α_C = α commanded

H_α = aircraft aerodynamics related to α

$\dot{\theta}$ = pitch rate

$G_{\dot{\theta}}$ = $\dot{\theta}$ feedback gain

$H_{\dot{\theta}}$ = aircraft aerodynamics related to $\dot{\theta}$

Ψ = angular heading

G_Ψ = Ψ feedback gain

H_Ψ = aircraft aerodynamics related to Ψ

$\dot{\Psi}$ = yaw rate

$G_{\dot{\Psi}}$ = $\dot{\Psi}$ feedback gain

T = time constant

Figure 10. Autopilot Symbols List

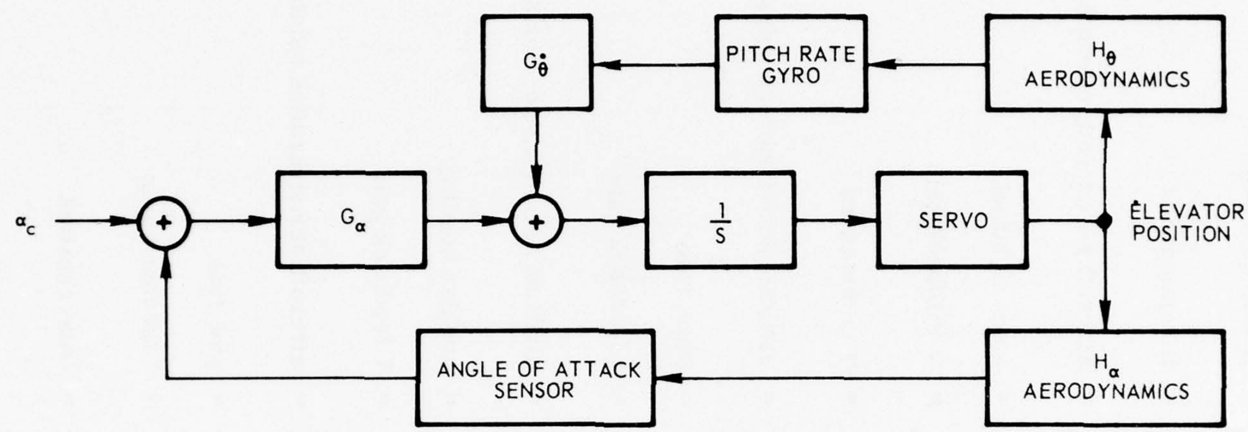

Figure 11. Angle-of-Attack Loop Block Diagram

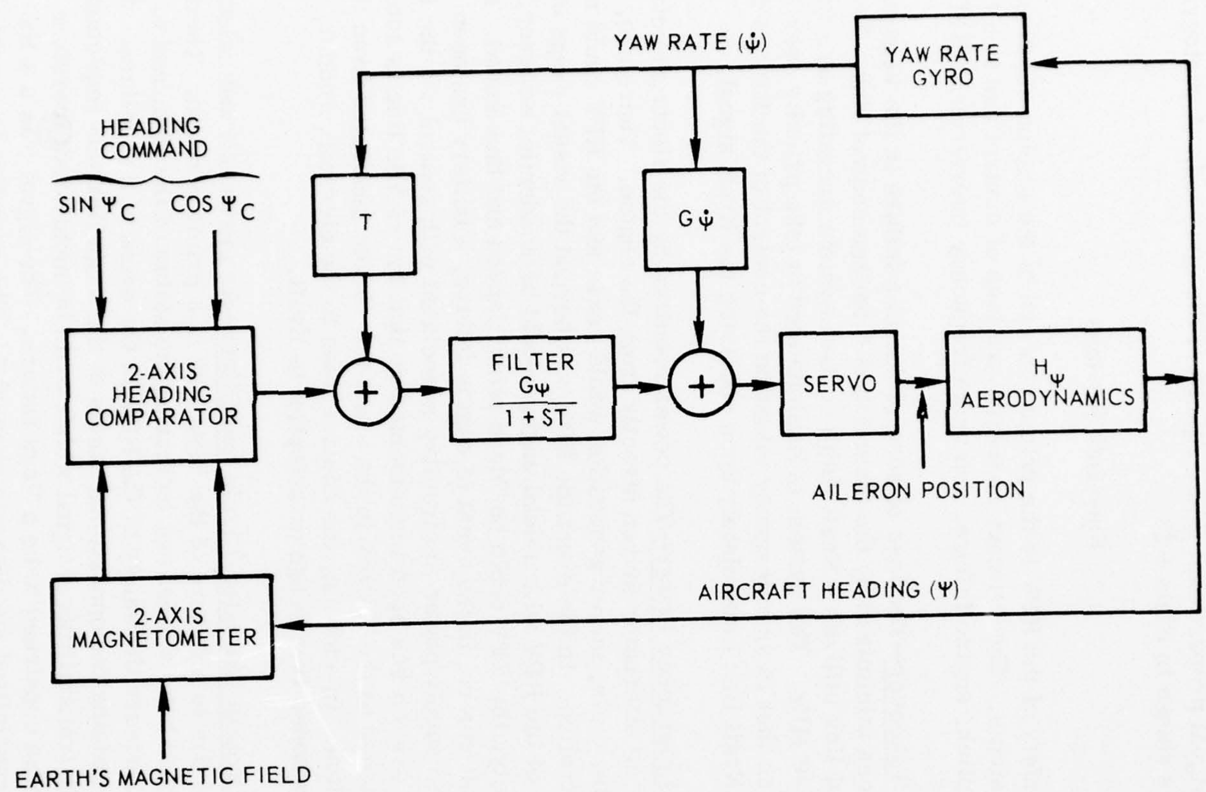

Figure 12. Heading Loop Block Diagram

station. The sensor is a pressure gauge that measures the dynamic pressure of the free airstream relative to the aircraft. This type of velocity sensor generates a signal proportional to the square of the airspeed. A photograph of the sensors is shown in Figure 13.

Fail-Safe Devices

The safety of the RPV is the prime concern of the implementation of the electronic systems. The primary concerns are loss of control due to a failure of the Vega uplink, engine failure, and radio frequency interference (RFI).

Kraft Takeover—The loss of control due to a failure in the Vega uplink system has been minimized by the inclusion of a backup control link. The backup control link utilizes a Kraft radio control system operating at a frequency of 72.40 MHz. The system is implemented to take priority over the Vega system so that in an emergency situation the control of the RPV is transferred to the Kraft link immediately upon receiving the Kraft signal.

Kraft Emergency Power—The power required by the electronic circuitry is supplied by an alternator driven directly from the engine. Therefore, in the event the engine quits, power generation would cease and the RPV could no longer be controlled. In the event the RPV was beyond the visual range of the pilot, control of the RPV with a dead engine would be academic; however, in the near vicinity, the RPV could be "dead stick" landed and thus saved. In order to permit control in the event of engine failure, a battery has been implemented to supply power to circuitry associated with control via the Kraft system. The system has been implemented so that the +5 Vdc line is automatically switched to the battery in the event the +5 Vdc generated from the alternator is lost. In addition, the control lines to the elevator, rudder, and throttle are switched from Vega or autopilot to Kraft.

Vega Dropout Indicator/Circle and Climb—As previously indicated, the loss of control due to a failure of the Vega link is a prime concern. Therefore it is necessary to have a means of indicating the status of the link, and to take some action to assure the safety of the RPV in the event of that failure. A means of determining the operational status of the Vega link was implemented by continuously transmitting a signal which could be monitored; therefore loss of that signal was construed to be a Vega failure. The signal was a 4 Hz square wave transmitted via discrete channel 5. The autopilot is capable of flying the RPV without any direct control from the ground, utilizing preprogrammed on-board commands. Therefore, the loss of the Vega signal was implemented so as to transfer control of the RPV to autopilot, preprogrammed

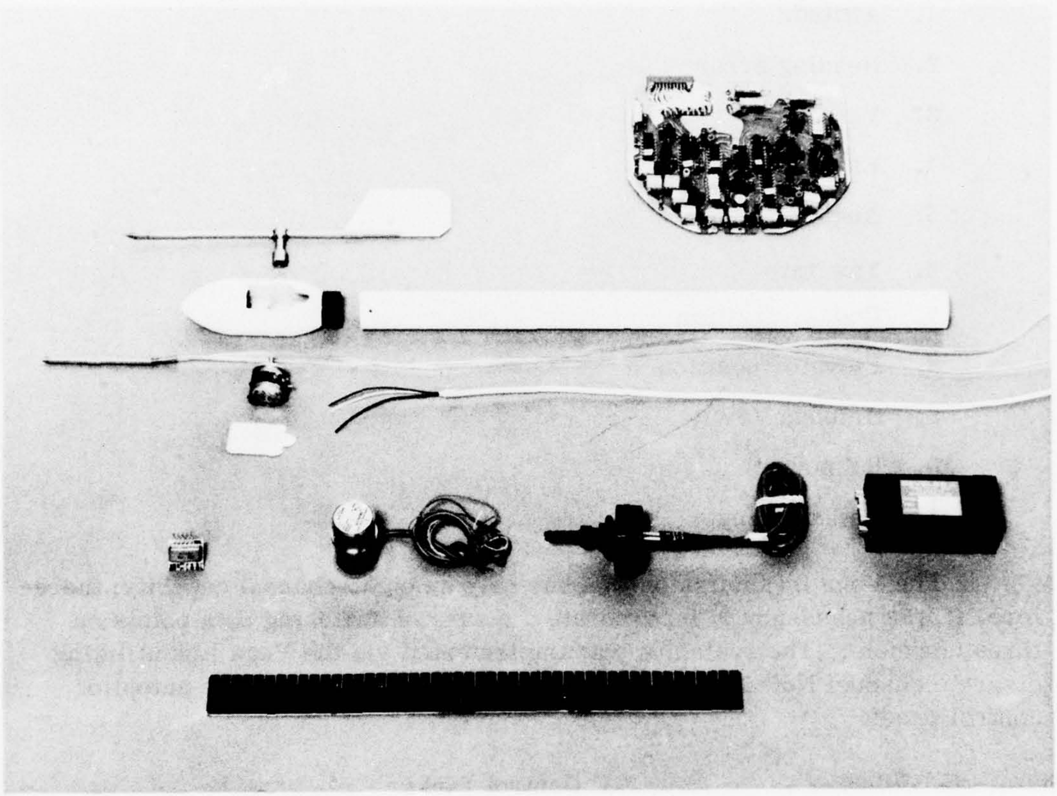

Figure 13. Autopilot Flight Sensors

to circle left and climb to a preset altitude, thus permitting time to re-establish the Vega link or transfer to Kraft.

Downlink Telemetry

The downlink telemetry is incorporated so that the ground controller can determine the in-flight status of the RPV and the on-board jammer. The data is transmitted via the Vega RF link and consists of:

1. Altitude
2. Heading error
3. Velocity
4. Engine RPM
5. Angle of attack
6. Yaw rate
7. Rudder position
8. Elevator position
9. Antenna VSWR
10. RF power
11. Antenna length

The Vega transmission link has only an eight-channel capacity; therefore, it was necessary to incorporate a means of switching data points on three channels. The switching was implemented via the Vega link utilizing discrete channel No. 4, which was controlled by a switch on the autopilot control panel.

RF Control Links

General Description of Vega Tracker/Control System—The Vega system combines the functions of tracking, position display, and a full duplex data link into one integrated unit. The system consists of a ground-located radar beacon tracking station and an airborne transponder/encoder-decoder. The beacon tracking system produces a slant range and bearing information which is displayed on an X-Y plotter, thereby indicating the position of the beacon. The communication link is implemented by a four-pulse code format employing pulse position modulation. The communication link employs time division multiplexing to provide six proportional channels and eight discrete channels on the uplink and eight proportional channels on the downlink.

Ground System—The ground station consists of three separate packages, i.e., the antenna unit, the radar controller, and the plotter. A photograph of the ground station is shown in Figure 14. The antenna unit contains all the RF components, i.e., the antenna, the transmitter, and the receiver. The antenna is a cosecant squared configuration producing an antenna pattern with 5-1/2° horizontal beam width and a 17° vertical beam width. The tracking signal uses a dual beam-null seeking concept which is implemented through the use of two antenna probes which are electronically switched in the receive mode. The transmitter produces a peak pulse power of 1500 watts at a pulse width of 0.3 microsecond. The repetition rate of the four pulse code is 500 Hz.

The receiver is a superheterodyne type exhibiting a sensitivity of approximately -80 dBm. The bandwidth of the receiver is 10 MHz at an IF frequency of 70 MHz. The receiver and transmitter will tune over a frequency range of 5.400 to 5.900 GHz and was tuned to 5.825 and 5.725 GHz, respectively, at Fort Huachuca.

The radar controller includes the encoder and decoder associated with the data link, the antenna control circuitry, etc. As previously mentioned, the uplink has a capacity of six proportional channels and eight discrete channels, while the downlink has a capacity of eight proportional channels. The proportional channel encoder accepts a voltage continuously variable from 0 to +5 Vdc and has a 30-Hz bandwidth. The data link has a 1:1 transfer frunction; i.e., the voltage level which is applied to the encoder is produced by the decoder. However, the resolution is limited to ±5 millivolts. The level into the discrete channels is either 0 or +5 Vdc and also has a 1:1 transfer function. The discrete channels incorporate a smoothing arrangement which reduces the bandwidth to 5 Hz.

The plotter accepts the bearing and slant range information from the radar control unit and translates the information into a continuous position plot of the RPV.

Airborne System—The airborne system consists of a transponder (model 349C), an encoder/decoder (model 765), and an antenna. The airborne system, unlike the ground system, does not transmit continuously, but only upon reception of a signal with the proper format. The video replica of the received signal is applied to the encoder/decoder module. Upon recognition of the proper signature (namely, the first two pulses with a 5-microsecond spacing)

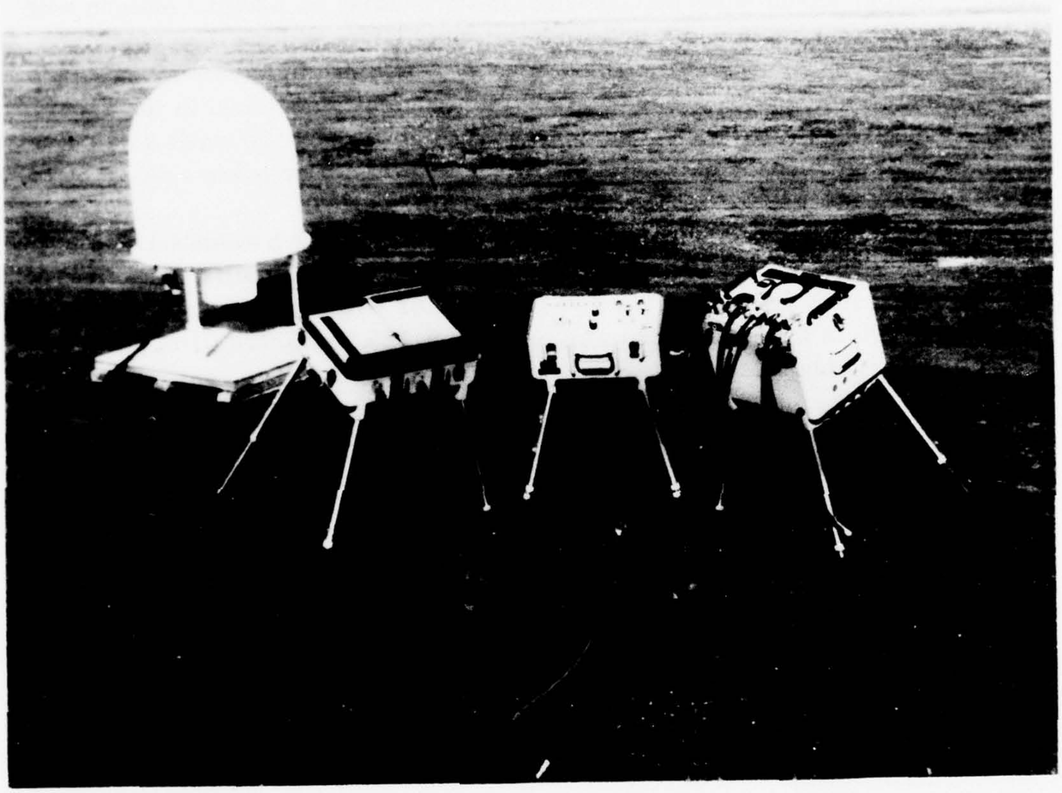

Figure 14. Vega Ground Station

the signal is decoded. In addition, after a fixed delay, the four-pulse code containing the downlink data is transmitted.

The transmitter pulse width is 0.4 microsecond with a peak pulse power of 5 watts. The receiver is of the superheterodyne type with a sensitivity of approximately -70 dBm, a bandwidth of 20 MHz, and at an IF frequency of 70 MHz.

The transmitter and receiver tune over a frequency of range of 5.400 to 5.900 GHz and were operated at 5.825 and 5.725 GHz, respectively, at Fort Huachuca. The transponder has a power requirement of +24 Vdc at a current of 50 mA.

The decoder/encoder has an uplink capacity of six proportional channels and eight discrete channels. The downlink has a capacity of eight proportional channels. As in the ground station, the input/output range is a continuously variable 0 to +5 Vdc range at a 30-Hz bandwidth for the proportional channels and 0 or 5 Vdc for the discrete channels. The power requirement is +24 Vdc at a current of 450 mA.

The antenna is omnidirectional, exhibiting a typical doughnut shaped pattern.

Kraft Command and Control System—The Kraft system is a commercial radio control link which consists of a ground control transmitter, an airborne receiver/demodulator, and the associated servo control actuators. The control link has a capacity of seven proportional channels implemented in an eight-pulse modulation format utilizing pulse position modulation. The system is unique in that the transmission of a pulse consists of turning the transmitter off as opposed to the conventional transmission of a signal. The frequency of the transmitter is 72.40 MHz at a power output of approximately 400 milliwatts with a pulse width of 400 microseconds. The repetition rate of the eight-pulse sequence is 50 Hz. The transmitter operates from a self-contained 9-V rechargeable battery.

The receiver is of the superheterodyne type, exhibiting a sensitivity of 3 microvolts, a bandwidth of 6 kHz, and an IF frequency of 455 kHz. The video replica of the received signal is demodulated and processed in the form of seven separate variable width pulse trains, each occurring at a 50-Hz repetition rate. The control actuators are position servos which are driven directly from the demodulator output. The position of the servo is directly proportional to the width of the control pulse train.

Launcher

The RPV's are launched from a truck-top launcher in order to more reliably attain launch velocity at short, unimproved sites. The launcher is essentially a cradle providing a three-point support for the RPV. (See photograph, Figure 3.) The RPV is held onto the cradle via a cable attached slightly forward of the center of gravity (CG) of the RPV (the cable is fastened to the cradle via a quick-release mechanism). The cradle is attached to the launch platform at a single pivot point at the forward end, thereby permitting a caster effect, which is limited at approximately ±30 degrees. The caster effect allows the RPV to face into the wind in the event it is necessary to launch the RPV in a cross wind. The cradle also includes a counter-balance arrangement which is adjusted so that the cradle exhibits a weight that is equal to 20% of the weight of the RPV at the CG. The additional weight assures a good lift-off from the launcher when the RPV is released. As the ground speed that is required to lift the RPV is affected by the wind, a positive lift indicator is incorporated into the launcher to assure adequate speed prior to release. The point at which lift-off is acquired is monitored by a switch arrangement attached to the cradle, and is indicated by a light inside the cab of the truck. Upon attaining an indication of lift, the RPV is released via a hand mechanism actuated from inside the cab of the truck.

Jammers

Two separate jammers are used on this task: a narrow band (spot) jammer designed and fabricated under this task and an ASA barrage jammer supplied as GFE. The two jammers are packaged so as to be directly interchangeable.

Narrow Band Jammer

General Description—The narrow band jammer is operated in a "hands-on" mode, with the frequency and dispersion controlled from the ground via the Vega link. The jammer comprises four major building blocks: the wide band power amplifier, voltage controlled oscillator, frequency/dispersion control, and power leveling/VSWR (voltage standing ratio) shutdown circuitry. A block diagram of the jammer is shown in Figure 15.

Variable Frequency Source—The frequency source for the jammer is the MC1648 voltage controlled oscillator (VCO). It is an integrated circuit capable of tuning up to 150 MHz with the appropriate varactor diodes. The

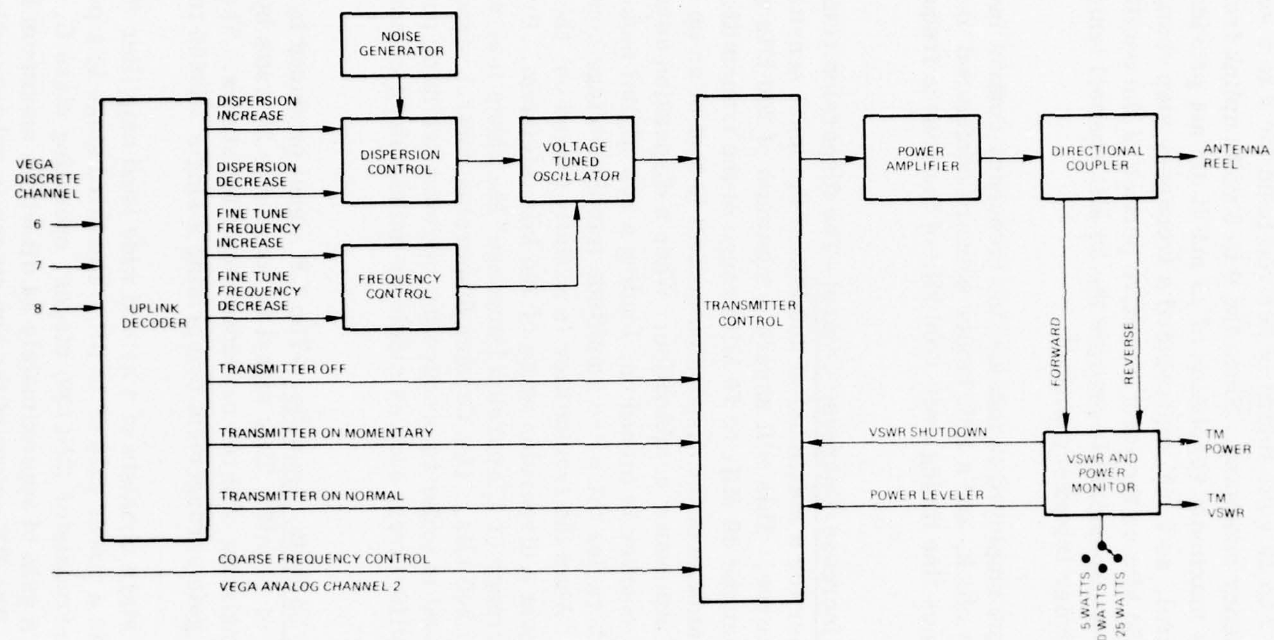

Figure 15. Spot Jammer Block Diagram

oscillator is very simply implemented in a separate RFI compartment in the jammer package and covers the 30 to 76 MHz range with a tuning voltage of 2 to 10 volts. The 2 to 10 volts tuning is derived from the 0 to 5 volts Vega analog uplink frequency command. Since the 0 to 5 volts uplink from the Vega radar control has a maximum resolution of ±5 mV it did not provide adequate fine frequency control, as 5 mV represented a frequency step change on the oscillator of up to 50 kHz on the most sensitive portion of the oscillator tuning curve. This made it impossible to provide the 30 kHz channel tuning without implementing a Vernier frequency control.

The technique employed to include fine frequency control involved an up-down counter, a clock, and a R2R ladder network configured to provide essentially continuous fine tuning over ±200 kHz of the coarse frequency setting.

Dispersion Increase/Decrease Control—The dispersion control is preset in the jammer for a maximum of 200 kHz at the least sensitive point on the voltage tuning curve. This will assure a minimum of 200 kHz wide jam signal anywhere over the 30 MHz to 76 MHz range of the transmitter. The technique used to implement the dispersion control is that of an up-down counter and digital attenuator combination. When a dispersion adjustment is commanded, the counter is turned on, loading a new digital number into the attenuator which varies the noise amplitude into the voltage controlled oscillators (VCO). When the transmitter is initially turned on, the control is arranged to present a dispersion width of 100 kHz minimum. By commanding "Dispersion Increase or Dispersion Decrease" the range may be varied over a width of 0 to 200 kHz. The Vernier dispersion control versus a fixed preset control is used in order to produce the optimum jamming power density for the specific threat such as single or multichannel communications links.

Wide Band, 25 Watt, Amplifier—The RF signal produced by the VCO is at a power level of 10 mW. This signal is boosted to 25 watts by a wide band amplifier, consisting of three cascaded amplifier stages. The first stage is a variable gain arrangement comprising a single 2N3866 transistor.

The second stage consists of a hybrid wide band amplifier (Motorola MHW 561) which has a power gain of 14 dB. The third stage is a parallel arrangement of two transistor (2N6199) stages, operating class C. The transistors exhibit a gain of approximately 14 dB with a maximum RF output power of 30 watts. The RF output of the two stages is subsequently combined via a quadrature hybrid.

Power Leveling/VSWR Shutdown Circuitry—The power output level of the wide band amplifier varies from the low end of the frequency (30 MHz) to the high end (76 MHz) due to the inherent capacity of the transistors. Therefore, in order to maintain a constant power level across the frequency band, a power leveling circuit utilizing a closed loop feedback arrangement was incorporated. The feedback signal is obtained by rectifying a sample of the RF output signal. In order to prevent antenna mismatches from producing erroneous levels, the RF level is sampled via the forward port of a dual directional coupler. The dc level obtained from the detector is compared to a dc level known to be produced by a specific power level. The error voltage thus produced is utilized as an automatic gain control (AGC) voltage, which is applied to the first stage of the wide-band amplifier.

The phase of the AGC voltage is arranged so as to reduce the error voltage to zero. Some difficulty was encountered with the power leveling arrangement at the low-frequency (below 40 MHz) end of the band. The harmonic signals generated by the class C final stage added directly to the fundamental at the detector, thus producing an erroneous output. The feedback loop therefore changed the amplifier gain so that the sum of the signals was equal to that specified for the fundamental alone; thus the fundamental was incorrect in this case below the specified power level. A low pass filter with a corner frequency of 76 MHz was subsequently incorporated between the amplifier and the directional coupler. However, as the bandwidth (30 to 76 MHz) is greater than an octave, the second harmonic of frequencies below 38 MHz could not be attenuated. The low pass filter improved the power leveling, maintaining a constant level from 76 MHz to 40 MHz. However, over the frequency band of 40 MHz to 30 MHz the power output was reduced by 1.2 dB. To maintain a constant power level over this frequency range it would be necessary to include a second low pass filter with a corner frequency at mid band, thus necessitating a switching arrangement between the two filters. The power leveling circuit is also utilized as a means of varying the output power level, by selecting a reference voltage proportional to 5, 10, or 25 watts via a switch accessible through an access hole in the cover.

The transmitter also incorporates a means of preventing a large mismatch at the RF output port (and thus a high VSWR on the transmission line) from damaging the output transistors. The damage is due to thermal overload since the RF power normally radiated by the antenna is reflected back into the transmitter and dissipated in the transistors.

The VSWR shutdown is actuated by a dc voltage proportional to VSWR, which is obtained from the reflected port of the dual directional coupler used in the power leveling circuit. The VSWR shutdown network is a closed loop arrangement implemented by comparing the feedback signal to a dc level known to be produced by a specific VSWR (in this case a VSWR of 2:1 at a power level of 25 watts). The error voltage is implemented to control the AGC level (in conjunction with the power leveling error voltage) so as to reduce the output power level of the transmitter.

VSWR Indicator—The VSWR indicator provides a means of monitoring antenna quality via the telemetry link. VSWR is defined by the equation VSWR = $V_F + V_R / V_F - V_R$ where V_F is the incident RF voltage on the transmission line and V_R is the reflected voltage. A dual directional coupler is utilized to obtain V_F and V_R. The mathematical operation is performed through the use of an analog and digital circuit implementation.

Fail-Safe Controls—Due to the obvious implications of placing a jammer on-board the aircraft, certain other "fail-safe" features become appropriate. The dilemma of jamming the aircraft with its own jam transmission had to be avoided. This consideration led to the implementation of a ground initiated jammer turn-on scheme, which was automatically turned off in the airborne package 3 seconds later. Several "momentary on" cycles allowed pilot and telemetry observers to verify proper autopilot performance and avoided the possibility of the aircraft being jammed and thus unable to turn the jammer off. In addition, the jammer was automatically turned off in the event of "loss of signal" or if Kraft control was introduced.

Barrage Jammer—The barrage jammer, as furnished by ASA, was contained in a package 8 inches x 5 inches x 5 inches. The jammer in that configuration was too large and heavy for direct installation in the RPV. In addition, the barrage jammer was required to be directly interchangeable with the spot jammer. In order to meet the interchangeability requirement the barrage jammer was repackaged, and the items not needed in this application were removed. The jammer consisted of the RF circuitry (3 modules), two nickel-cadmium rechargeable batteries, and two control timers. The control timers were utilized for automatic unattended, turn-on and turn-off of the jammer. As the jammer control was instrumented via the Vega control link, the timers were no longer necessary and were omitted. The form factor and weight of the nickel-cadmium batteries precluded their use. The power required by the jammer was furnished directly from the on-board alternator on the E-100, and by the addition of a lithium battery pack in the E-45. The lithium cells were chosen for their excellent power-to-weight capability. The remaining RF circuitry consisted of three modules, which were repackaged so as to be directly interchangeable with the spot jammer.

Jammer/RPV Integration—The jammer was installed in the nose of the E-45 and was accessible by removing the nose cone. As the E-45 alternator does not produce sufficient excess power to operate the jammer, a lithium battery pack was used which was attached directly to the jammer, thereby forming a single integrated package. The narrow band jammer contained an integral, multiple fin heatsink to prevent excessive temperature rise. When operating at the 5 and 10 watt RF power levels, natural conversion was adequate; however, for continuous operation at the 25-watt level, it was necessary to provide forced air cooling. In-flight cooling was implemented through the use of ram air obtained via two holes located on the front of the nose cone. The jammer mounting bracket was utilized to form a duct directing the ram air over the heat sink and ultimately to the exhaust port located on the bottom of the nose cone.

On the E-100, the jammer was located on the left-hand side of the vertical bulkhead. The E-100 alternator has adequate power available; thus, a battery pack was not necessary. The ram air cooling was obtained via a scoop located on the hinged cover (see Figure 7) and was directed over the heatsink via a duct built into the mounting bracket and subsequently exhausted via a second port.

Antenna Reel

Mechanical Design—The antenna reel mechanism as envisioned would include a drive motor, reel, potentiometer, retraction and extension limit switches, and a means of terminating the coaxial input feed onto the rotating reel. This assembly would be sized to fit into either aircraft with only minor modifications in mounting, and would be located as close as possible to the aircraft CG to limit induced moments due to maneuvering loads.

This antenna material was first determined as to strength, size, temper, and material that would withstand the flight envelope and be electrically efficient. Beryllium copper No. 25, heat treated to 1/4 hard, was determined to be of sufficient strength and yet elastic enough to be stored on a small diameter reel. The diameter was also selected as 0.020 in. single strand.

This selection allowed calculations to be made on induced drag and the weight necessary to keep the antenna within a 20° angle of attack at expected flight velocities.

The reel and drive motor were designed using the torque values obtained from the previous calculations. The reel was designed as a single wire-upon-wire stack in order to simplify the reel and delete the need of a lateral follower. Using a 1-inch-diameter hub, approximately 22 turns provided the maximum antenna length of 94 inches in a 2-inch-diameter reel. The motor selected was a Globe Type SS equipped with a 12-V armature and a 485-to-1 gear drive, allowing a maximum torque of 70 oz. in. at an output speed of 20 to 25 rpm. Time to extend to the maximum length would be approximately one minute, which was judged to be acceptable.

The reel would be electrically hot, so it had to be insulated from the motor and all chassis pieces. A small RF rotary joint was located that would be acceptable to use as the means of running the RF from the external non-rotating input to the rotating reel. The reel itself is insulated by nylon spacers on each side with nylon screws holding the reel halves to the rotary joint and motor drive shaft. Gearing was provided in order to drive the 10-turn proportional length control potentiometer within the full length extraction of the antenna line. To insure cutoff at both the retraction length and the full extraction length of the antenna line and also to protect the 10-turn pot from overdrive, two stops were incorporated. The retraction stop was a microswitch activated by a lever that closed with an adjustable stop on the antenna line itself. However, the extraction stop had to be made through the gear drive in order to stop the motor and protect the pot. A precision spur gear driven off the pot shaft was used plus a worm drive to reduce the speed and to allow actuation of a microswitch through a pin on a rotating wheel.

A layout of this design was made using overall dimensions that would allow placement in both the E-45 and E-100 close to the CG but not requiring any major airframe redesign.

Two plates were used with nylon spacers between to contain and mount the drive motor and other reel components. (See Figure 16.) Weight of the drive unit without the external antenna weight was 1.30 pounds.

A weight at the end of the antenna line is necessary to keep the antenna as vertical as possible. Calculations showed that about 1.5 pounds was necessary for the E-100 velocity, expected to be 90 to 100 mph, at the maximum antenna length of 9 feet. A weight design was made based on a low drag fat streamline object with a 1.5-pound weight cast from a Cerrobend low melting point lead alloy. Vertical fins were added for directional stability. Fabrication was made using a cast, 2-piece mold of Devcon. Connection to the

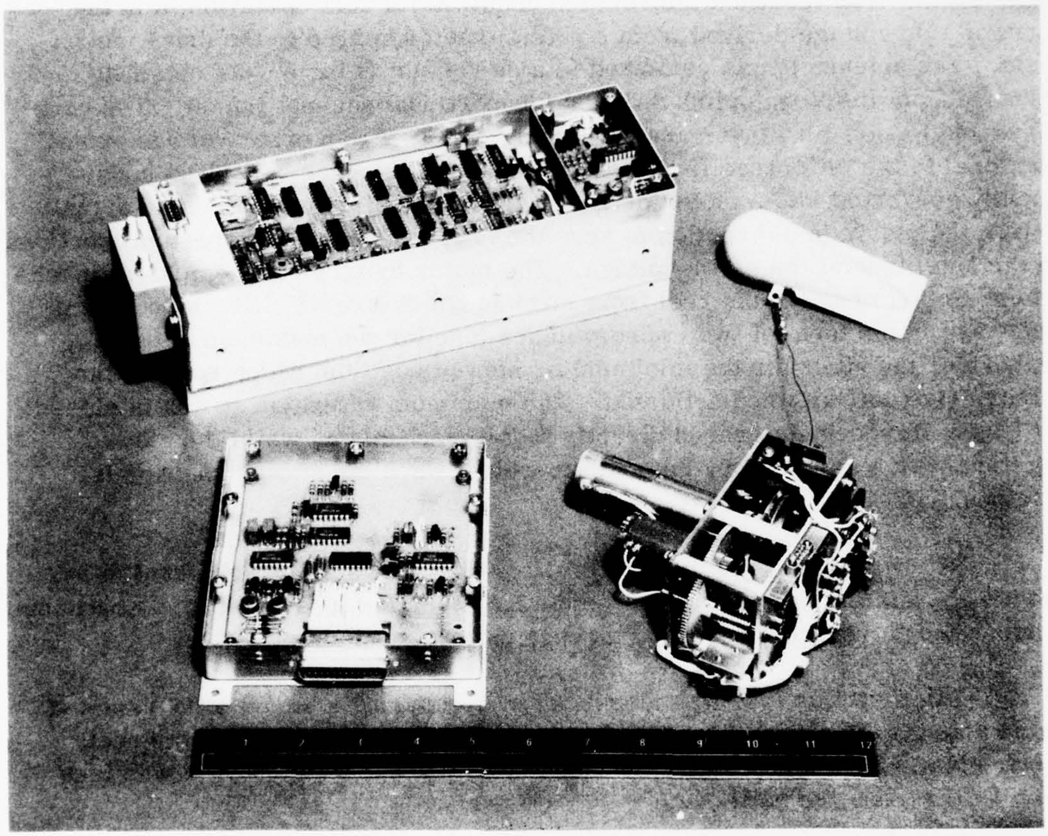

Figure 16. Antenna Reel/Spot Jammer

antenna line was through a space type fastener tapped into the weight body at the CG.

Electrical Design—The electrical drive to the reel motor is a closed loop servo arrangement permitting the remote operator to command any specific length. The feedback information required for this operation is in the form of a dc voltage derived from a potentiometer geared to the drive mechanism. The antenna length command is a dc voltage (0 to +5 Vdc) obtained directly from the Vega uplink decoder (proportional channel No. 3). The command and feedback voltages are compared, producing an error voltage proportional to the difference in the two voltages. The error voltage is subsequently converted into a motor drive signal. The polarity of the drive signal drives the motor in a direction to zero the error voltage, at a speed proportional to the amplitude of the error voltage. The motor drive circuit employed mechanical stops to protect the reel from mechanical overdrive. The mechanical stops are in the form of two microswitches (one for the maximum antenna extension, the other for the minimum or stowed position) which remove the motor drive voltage when activated. The maximum extension switch is closed by a cam arrangement geared directly to the mechanism, while the stowed position switch is closed by the antenna weight when the stowed position is attained.

RF Characteristics and Calibration—The antenna was subjected to a series of tests in order to determine the RF insertion loss of the reel, optimum antenna length versus frequency, antenna pattern, and antenna gain.

The insertion loss was measured by comparing a signal level radiated by an antenna fed directly, versus the same length antenna fed via the reel mechanism. Although the loss varied as a function of frequency, it was less than 1 dB across the band.

The optimum antenna length versus frequency was established by adjusting the length so as to minimize the VSWR exhibited by the antenna while operating at a fixed frequency. The initial tests disclosed erratic VSWR reading at the lower frequencies which was attributed to an inadequately large ground plane. The ground plane was enlarged by the addition of metal conductors along the entire length of the wing (120"). The subsequent test data more nearly followed the predicted curves; however, undesired resonances occurred between 60 and 70 MHz. The radials were then shortened to a total length of 97" which eliminated the resonances.

The antenna pattern measurement was made through the use of frequency scaling techniques as the large size of the RPV and the low frequency of operation (thus long antenna lengths and the associated measurement problems due to ground reflections) would require special fixtures which were beyond the scope of this task. In frequency scaling, the physical size of the frequency related structures (antenna length and air frame) are inversely proportional to the change in frequency; for example, a 10:1 increase in frequency would require a 1/10 scale model of the antenna and RPV. The antenna patterns were made in an RF anechoic chamber whose frequency characteristics required a scaling factor of 34:1 for an actual frequency of 50 MHz. A simplified antenna model consisting of a whip antenna perpendicular to a circular ground plane was used for this test. The diameter of the ground plane was based on the RPV wing span of 120" which thus scaled down to a size of 3.5". The electrically small size of the ground plane (0.5 λ @ 50 MHz) produced a double hemisphere pattern like that of a typical dipole as opposed to a single hemisphere produced by a whip over a ground plane of adequate size (see antenna pattern as related to the RPV in Figure 17). The fact that the scale model antenna produced a dipole pattern was utilized during the flight test program when it became necessary to change from the extendable trailing wire antenna. Since the radiation pattern extended above the RPV when a 1/4 λ antenna protruded beneath the RPV, it was deduced that the reciprocal would occur when a 1/4 λ antenna protruded above the RPV. Thus, the RPV was reconfigured by removing the extendable wire antenna, and adding a fixed length, vertical antenna to the top of the RPV, thereby permitting operating at a fixed frequency as determined by the antenna length.

The gain of the antenna was determined by direct comparison of the radiated field strength of the antenna mounted on the RPV with that of a gain standard dipole. In this arrangement, the received field strength is a function of antenna efficiency and pattern (assumed to have a standard dipole shape as produced by the model). The gain of the antenna varied as a function of frequency; however, it was within 2 dB of the standard dipole across the frequency band. The effective radiated power (ERP) of the jammer is directly related to antenna gain as shown by the equation for ERP (ERP = $P_T G_T$ where P_T is the transmitter power and G_T is the antenna gain). A plot of ERP for a transmitter output power of 10 watts (40 dB) is shown in Figure 18.

Dynamic Testing of Extended Antenna—Shortly after the first weight was cast, a simple fixture was attached to a car-top carrier that supported a motor-reel and the antenna line with weight attached. The fixture hung about 12 inches over the right side of the car. Several runs were made on a hot, gusty day to determine the air flow effects at speeds up to 60 mph. Maximum length to the

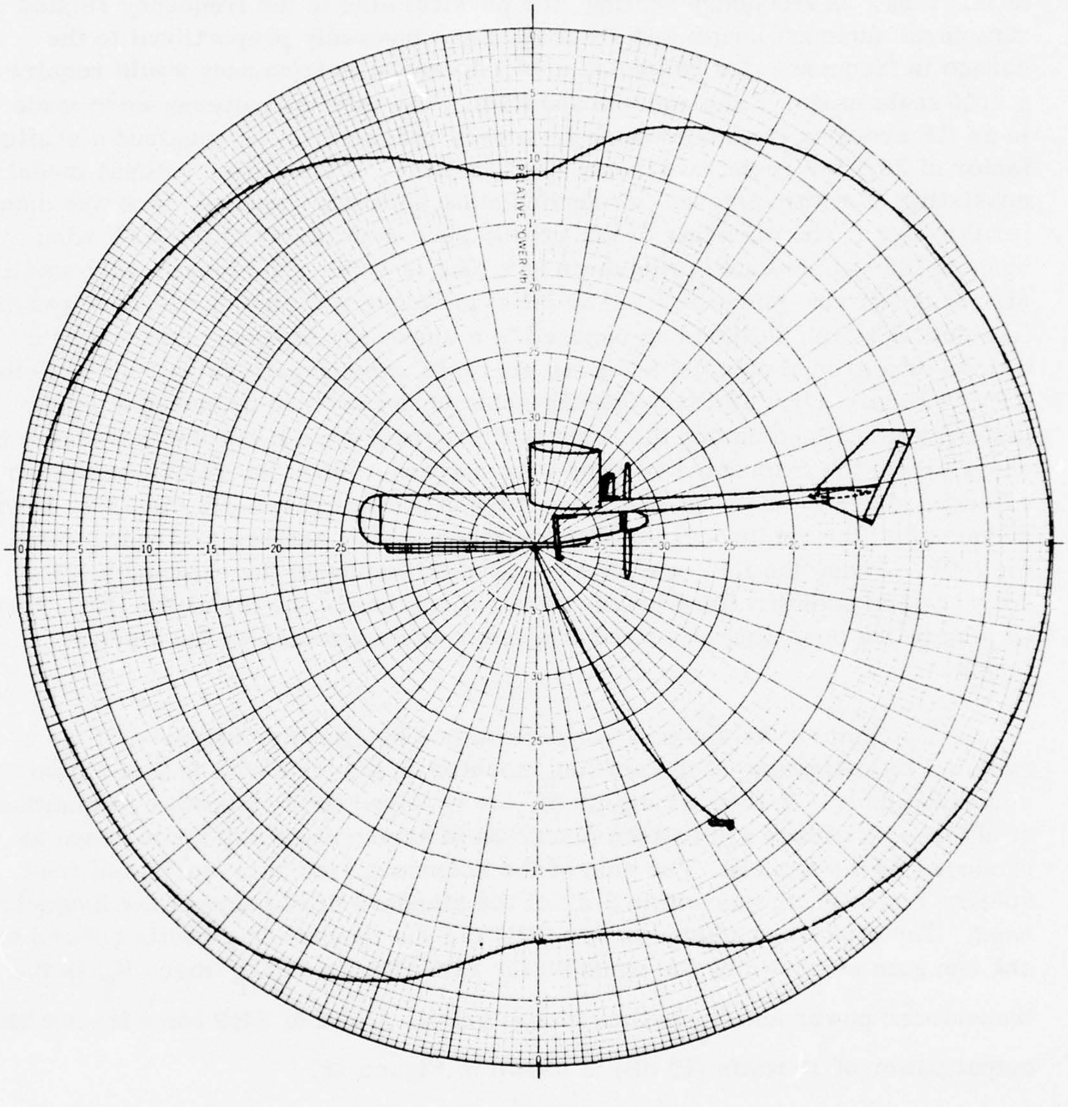

Figure 17. Typical Pattern Coverage in Flight

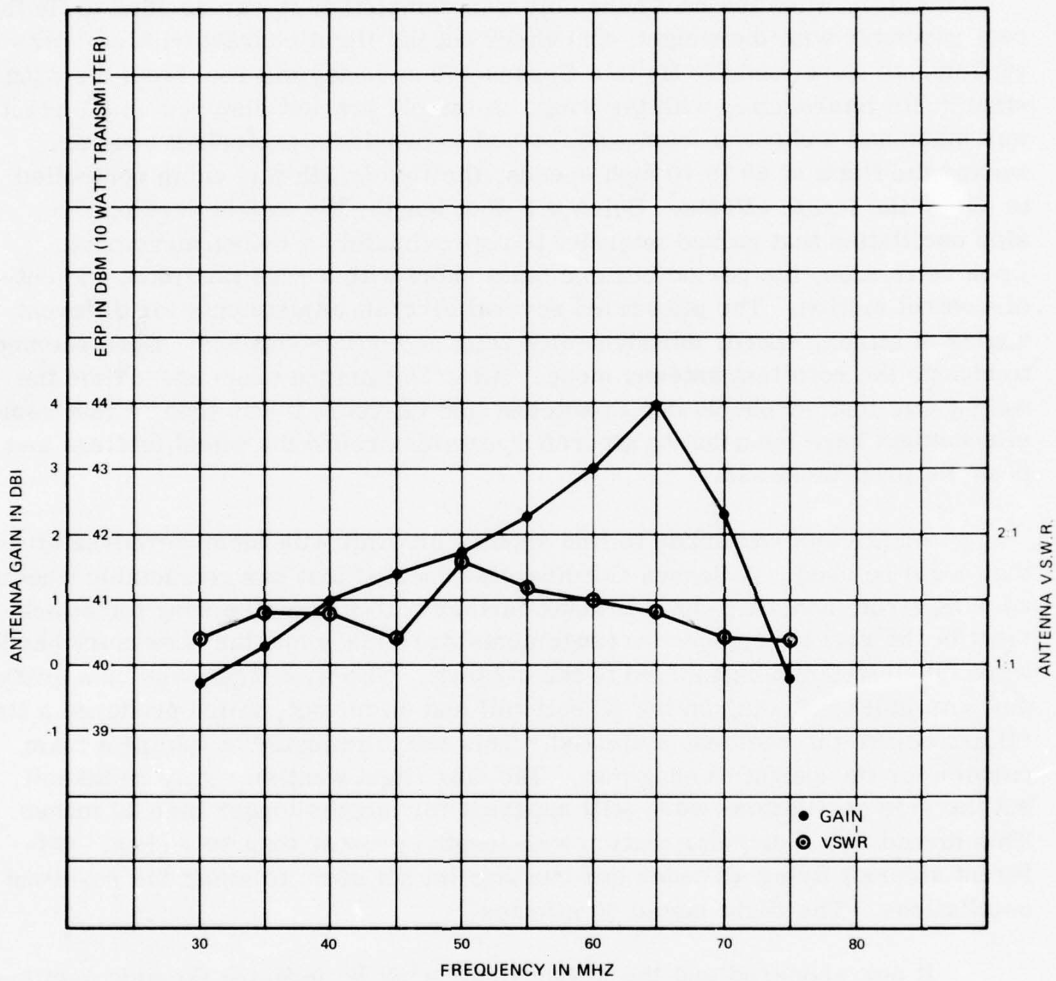

Figure 18. Antenna Characteristics vs. Frequency

ground was approximately 54 inches. The weight seemed extremely stable although some side movement was noticed, but it was attributed to the turbulence experienced in close proximity to the car body. The antenna line attack angle was well within the calculations at 6 to 7 degrees.

Later, when the reel assembly was completed, it was decided to fly the reel assembly with the weight, and check out the flight characteristics. Arrangements were made to fly in a Cessna 150 and hang the reel from the wing strut at its intersection with the wing. A simple bracket clamped on the strut was made and a sheet of foam was formed to provide a protective housing. During the flight at 60 to 70 mph speeds, the line length was cabin controlled to obtain the length effects. Below a 3-foot length, the weight developed a side oscillation that gained intensity to approximately a 6-foot movement. Upon retraction, the period became quite short with a resultant pitch and out-of-control motion. The pilot tried several aircraft adjustments for different angles of attack, speed, aerodynamics trim and power settings. None seemed to change the resultant antenna mode. After 25 minutes experiment time the weight was lost, probably due to antenna line fatigue. It was thought that some effect might have been due to aircraft dynamics around the wheel fairings and possible prop backwash.

An attempt was made to find another aircraft with clean aerodynamics that could be used. A Cessna Cardinal was located that has retractable wheels, no wing strut, and a tie-down bracket further outboard on the wing for attachment of the reel assembly. Arrangements were made and the necessary hardware fabricated and assembled to the aircraft. The first flight was on a gusty day with much bouncing on the takeoff roll and climb-out, which produced a line failure before the reel was activated. This was eliminated by adding a foam cushion for the weight to snug into. The next flight went smoothly on takeoff, but the side oscillations were still apparent for lengths longer than 30 inches. This turned into a circular motion with lengths greater than 80 inches. Different aircraft flying altitudes and banking did not seem to affect the resultant oscillations. The flight lasted 60 minutes.

It now appeared that the weight itself must be inducing the side oscillations even though several weights had been used. To more easily experiment with different weights, a 2- by 4-foot wooden scaffolding was built 10-1/2 feet high to be placed on a pickup truck. The aerodynamic shaped weight showed the same oscillatory tendency as before. Several other weights were tried without this problem. Fishing weights of a teardrop design were tried in weights of 20, 12, and 10 ounces. All seemed to be self-dampened if several stops were made during retraction. Changing from the teardrop to a cut-off teardrop shape did not appear to change the aerodynamic characteristics. Clearance problems in both E-45 and E-100 aircraft made the use of the teardrop design marginal. It was believed that a round sphere would create no different problems than a cut-off teardrop of about the same size. The drag of the sphere or teardrop would be increased from the original shape, which in turn would affect the angle of attack of the antenna. However, this was not sufficient to be a factor.

The flight tests were conducted using a cast lead weight, golf ball size, which minimized the clearance problems on the E-45 worst case. Attachment to the line was made by a cast-in-place shaft pinned to a fishing ball-swivel.

Ground Control Station

General Description—The ground control station is housed in a 16-foot step van in which two racks are assembled to hold control and monitoring equipment. A photograph of the control van is shown in Figure 19. Each rack of equipment is associated with a function relating to the autopilot operator or the jammer operator. Strategically located between the racks is the Vega radar control and plotting system. This arrangement presents convenient access by either operator to observe and manipulate radar control and plotting status.

Located on either external side of the van are junction panels required for ac power input (115 ac, 60 Hz), telemetry output for remote monitoring or recording, Vega radar cable feed-through to an antenna mounted on the roof or some other strategic location, coaxial connections for boosted RF Kraft control and jammer monitoring antennas, and finally inputs from the pilot control box used for the aircraft's manual mode.

This configuration allows the ground station to be an essentially independent and portable operation when provided with an ac power source. An example of this capability was demonstrated during Melpar's previous flight testing at Fort Huachuca on the East Range where the aircraft was launched from a dirt road and ac power was provided from a portable unit.

Communications between remote manual pilot, autopilot operator, and jammer operator are maintained by a sound powered headphone party system. Walkie-Talkies were used in preflight range control testing of the aircraft.

RPV Control—Essentially, the RPV has three modes of control. The description and purpose of each are as follows:

a. Remote Manual Control: This mode was used primarily for launch and basic aircraft checkout before transferring to autopilot while airborne. It allowed the aircraft to be placed in a safe attitude within visual observation in the event the autopilot performance turned out to be unsatisfactory. In addition, remote manual control serves as a backup during airborne autopilot checkout procedures. Since manual mode has priority over autopilot mode, the manual pilot has primary control. It is at his discretion whether the aircraft is transferred to autopilot or returned to manual. He has the option of doing this on an independent loop basis (heading, altitude, or angle of attack) or by transferring all three loops at one time. Under normal circumstances a mode transfer is requested by the autopilot operator.

Figure 19. Ground Control Van

b. Autopilot Mode: Once proper trim characteristics have been established for manual control, transfer to autopilot is in order. This is achieved by throwing three switches simultaneously or in sequence on the manual control box. An indication that such a transfer has taken place is communicated verbally over the sound powered phone system and verified electronically by appropriate light display on the autopilot control console. Autopilot commands can now be appropriately updated as necessary to achieve flight profile requirements. To assist the autopilot operator in the decision-making process of on-board status, eight channels of telemetry are available on the observer panel. Four primary channels, A/A, altitude, velocity, and heading error, are duplicated and placed strategically on the pilot control panel in a manner which minimizes visual clutter. Aircraft position is displayed on the radar plotter located adjacent to the AP operator. Mission objectives may now be undertaken by the use of three uplink commands. A clock-faced, 10-turn pot provides altitude commands; a calibrated slide pot commands proper angle of attack; and a compass dial provides heading commands. With these three simple controls, the autopilot operator can perform all maneuvers necessary for an autopilot mission.

c. Kraft Control Mode: Kraft control is a completely separate uplink command and control system. Its main purpose is to provide a fail-safe backup in the event of abnormal Vega radar control. Airborne electronics required for Kraft control are designed so that battery power will be provided should the on-board alternator fail. This system bypasses the majority of electronics associated with Vega control for either autopilot or manual control of the aircraft. This provides a significant margin of safety in regard to possible on-board electronics failure. Only manual control is available through the Kraft link. Introduction of Kraft control automatically inhibits the jammer transmitter.

Jammer Control—The jammer control panel contains all the functions necessary to operate the jammer and the telemetry display meters. The panel includes:

a. Coarse Frequency Control: 0 to 5 volt Vega analog uplink channel controlled by a 10-turn digital display potentiometer.

b. Fine Frequency Increase/Decrease: A spring-loaded, single-pole, double-throw toggle switch arranged conveniently to allow the operator to visually observe and remotely adjust the jam signal frequency with respect to the threat signal on the panoramic display.

c. Dispersion Increase/Decrease: A spring-loaded, single-pole, double-throw toggle switch arranged to remotely fine tune the dispersion while observing the threat signal bandwidth on the panoramic display.

d. On Momentary: A toggle switch that initiates a 3-second "on" state of the jammer but is turned off automatically through on-board electronics.

e. On Normal: A red lighted switch that is illuminated during normal jammer operation.

f. Antenna: 0 to 5 volt Vega analog uplink command controlled by a 10-turn digital display potentiometer.

g. Telemetry Data: Power out, antenna length and VSWR.

Telemetry—Basically, eight analog channels of 0 to 5 volts are provided with a resolution of ±5 mV. Three channels are switched at the discretion of the autopilot operator to provide jammer data. Telemetry channels and function are as follows:

Channel 1	Altitude
Channel 2	Heading Error
Channel 3	Velocity
Channel 4	RPM/VSWR
Channel 5	Angle-of-attack
Channel 6	Yaw Rate
Channel 7	Rudder Position/Jammer Power
Channel 8	Elevator Position/Antenna Length

Ground Support System

Ground Power Unit—The ground power unit (GPU) supplies all the power requirements of the RPV and in addition provides a means of testing the RPV power supply without running the engine. The GPU utilizes an alternator (identical to the on-board unit) driven by a universal ac motor to produce the power. The on-board unit is simply replaced by the GPU unit via an umbilical cable and a transfer switch. Thus, the rectifiers, filters, field regulator, etc. (necessary to produce the various dc voltages), are the on-board devices and can therefore be tested without the necessity of running the engine. The GPU also provides a convenient means of monitoring the power supply voltages (via a front panel meter), assuring proper power supply operation prior to applying power to the electronic circuitry. The GPU also provides the field flash voltage required to initiate the generation of power by the alternator.

Altitude/Velocity Simulator—The altitude/velocity simulator provides a means of dynamically testing the altitude control loop of the autopilot and the air speed indicator. The altitude simulation consists of a vacuum pump, a barometric altimeter, and associated plumbing. The simulator is connected to the on-board pressure sensor, permitting calibration of the altitude telemetry as well as testing the autopilot. The velocity simulator contains an air compressor, an air speed indicator, and the associated plumbing. The calibrated air pressure thus produced is connected to the on-board pressure sensor via the pitot tube, thus permitting calibration of the air speed telemetry.

Compass Rose—The compass rose is a test fixture used to calibrate the magnetometer and to test the heading loop of the autopilot. Because the magnetometer produces heading information from the earth's magnetic field, the fixture must be constructed from nonmagnetic material so as not to produce magnetic field distortions. The fixture is a holding cradle mounted on a turntable to readily permit measurements at all points of the compass. The turntable includes a means of leveling the RPV and is calibrated in 15° increments of compass headings.

FLIGHT TESTS

Seven flights were made during the period of 9 November to 23 November 1976. Prior to each flight a detailed preflight check of the RPV was conducted.

The preflight test procedure was designed to test and evaluate the complete system, i.e., control link, avionics, telemetry link, and ground control stations. The check list is shown in Figure 20 with a brief description of each step as follows.

The RPV is connected to the ground power unit (GPU) with the pod on-off switch in the off position. AC power is then applied to the GPU at which time the presence of the DC voltages utilized on board the RPV are verified on the meter located on the front panel of the GPU. If all voltages are present and of the proper level, the pod is turned on and the checkout begun.

1. This test is designed to check the rudder actuator, the Vega manual rudder control channel, and the operation and calibration of the rudder telemetry channel. The position of the rudder is determined by direct observation, utilizing a calibration fixture built into the vertical stabilizer. The rudder is moved by the operator of the Vega manual control until the desired position is obtained as determined by the observer at the RPV at which time the telemetry reading is recorded.

2. This test is designed to verify proper operation of the elevator actuator, the associated Vega manual elevator control channel, and the operation and calibration of the elevator telemetry channel. The position of the elevator is determined by direct observation utilizing a calibration fixture built into the horizontal stabilizer. This test is performed similar to that of the rudder.

3. This test verifies proper operation of the Angle of Attack (α) sensor and the associated telemetry channel. The α flag is manually positioned (utilizing a test fixture temporarily attached to the pitot tube assembly), at which time the telemetry reading is recorded.

4. This test is designed to determine the operation and gain of the angle of attack (α) loop of the autopilot, and the calibration of the α command control in the ground station. The autopilot controls the rate and direction of the elevator movement, not the position. Therefore, if the RPV α (as simulated by manually positioning the flag) is the same

		LEFT TURN					RIGHT TURN			
1	Left Rud/Ail									
	Right Rud/Ail	15°	10°	5°	2.5°	0°	2.5°	5°	10°	15°
	TM									

		UP ELEVATOR					DOWN ELEVATOR			
2	Elevator	15°	10°	5°	2.5°	0°	2.5°	5°	10°	15°
	TM									

3	α Flag	16°	14°	12°	10°	8°	6°	4°	2°	
	TM									

4	α Flag	10°	8°	6°	6°	10°	
	α Comm.				8°	8°	
	Δ Elevator				10°	10°	
	Time Δ Elevator						

		LIFT TAIL	DROP TAIL
5	Δ Up Elevator TM		
	Δ Down Elevator TM		

Figure 20. Preflight Check List

6

Simulated Altitude	0'	1000'	2000'	3000'	4000'	5000'
TM						

7

Altitude Comm.	1000'	
Max Throttle		
Min Throttle		

8

Simulated Velocity-Knots	30	40	50	60	70	80
TM						

9A

Heading	000°					
Heading Command						
Heading Error TM	L-30°	L-10°	0°	R-10°	R-30°	
Rudder Def. TM						
G Ψ						

Figure 20. Preflight Check List (Continued)

	Heading	090°					
9B	Heading Command						
	Heading Error TM	L-30°	L-10°	0°	R-10°	R-30°	
	Rudder Def. TM						
	GΨ						

	Heading	180°					
9C	Heading Command						
	Heading Error TM	L-30°	L-10°	0°	R-10°	R-30°	
	Rudder Def. TM						
	GΨ						

	Heading	270°					
9D	Heading Command						
	Heading Error TM	L-30°	L-10°	0°	R-10°	R-30°	
	Rudder Def. TM						
	GΨ						

Figure 20. Preflight Check List (Continued)

		Right Turn (+dcV)					Left Turn (-dcV)				
10	Yaw Deg/sec.	10°	8°	6°	4°	2°	0°	2°	4°	6°	8°	10°
	Sim. Yaw Voltage	1.0V	.8V	.6V	.4V	.2V	0V	.2V	.4V	.6V	.8V	1.0V
	Yaw TM											

		Yaw Nose Right	Yaw Nose Left
11	Δ Yaw TM	Left	Right
	Δ Rudder TM	Left	Right

12	RPM	3000	5000	7000	8000		
	TM						

		Circle & Climb	
13	Rudder °		
	Commanded Alt.		
	UpEl. above Comm.		

Figure 20. Preflight Check List (Continued)

14A

	Freq.						
	5W	10W	25W	Barrage	1:1	2:1	3:1
RF Power							
RF Power TM							
VSWR TM							
Freq. Comm.							

14B

	Freq.						
	5W	10W	25W	Barrage	1:1	2:1	3:1
RF Power							
RF Power TM							
VSWR TM							
Freq. Comm.							

14C

	Freq.						
	5W	10W	25W	Barrage	1:1	2:1	3:1
RF Power							
RF Power TM							
VSWR TM							
Freq. Comm.							

Figure 20. Preflight Check List (Continued)

15	Ant. Length	30	40	50	60	70	80	90
	Ant. TM							
	Ant. Comm.							

Figure 20. Preflight Check List (Continued)

as the α commanded, the elevator will not move. The ground control command is positioned so as to stop the elevator movement at which time the α commanded is recorded.

The second part of the test is designed to measure the gain of the elevator loop of the autopilot. The elevator rate is proportional to the error between the commanded α and actual α (in this case, a 2° error is set up and the elevator timed for a movement of 10°).

5 This test was designed to verify operation of the pitch gyro and the associated autopilot circuitry on a go/no-go basis. The RPV is physically moved which results in movement of the elevator as verified via the telemetry.

6 This test is designed to determine the status of the altitude sensor, the associated electronics, and the telemetry channel. The altitude test box is utilized to simulate the particular altitudes at which time the telemetry reading is recorded.

7 This test is designed to determine the operational status of the altitude loop of the autopilot as well as the loop gain. The throttle position is proportional to the error between the commanded and actual altitude. In this test a 1000-foot altitude is commanded, and the simulated altitude is adjusted until minimum and maximum throttle is just achieved, at which time the simulated altitudes are recorded.

8 This test is designed to determine the operational status of the velocity sensor, associated electronics, and the telemetry channel. The hose from the velocity test box is attached to the pitot tube and the air pump inside the test box is run until the desired velocity is indicated on the air speed indicator at which time the telemetry reading is recorded.

9 This test is designed to check the magnetometer, the heading loop of the autopilot, and the telemetry channel. For this test the RPV is installed on a rotatable fixture set on a compass rose which has been set up away from all metallic objects and aligned to be level. The fixture is positioned so as to align the RPV for a heading of 000° (in the case of test 9A). The heading command to the RPV is then adjusted until the desired heading error is indicated on the telemetry (for example, a commanded heading of 030° should produce a heading error of LEFT 30°) at which time the commanded heading is recorded.

In addition, the rudder deflection is recorded at each heading error which is utilized to compute $G\Psi$. Due to the method of implementing the electronic circuitry this test must be repeated at RPV headings of 090°, 180°, 270°, (tests 9B , 9C , and 9D , respectively).

10 This test is designed to check the operation and calibration of the yaw rate telemetry channel. A dc voltage is used to simulate the gyro output (the voltage amplitude is proportional to the turn rate, while the polarity is determined by the direction of turn) at which time the telemetry indication is recorded.

11 This test is designed to check the operation of the yaw rate feedback loop of the autopilot on a go/no-go basis. The nose of the RPV is physically moved at which time the indication of rudder movement and yaw rate on the telemetry channels are recorded.

12 This test is designed to check the tachometer circuitry used to measure engine RPM and the associated telemetry channel. The ac voltage produced by the alternator is used to trigger the tachometer circuitry; therefore, as the GPU consists of an identically driven alternator, the tachometer circuitry can be tested without running the engine. The speed of the GPU motor is set via a front panel control for the desired RPM (as verified by a mechanical tachometer) at which time the telemetry indication is recorded.

13 This test is designed to check the circuitry which commands circle and climb in the event of the loss of the Vega uplink. As previously mentioned the presence of the Vega uplink is signified by a 2-Hz square wave transmitted on discrete channel No. 5. This signal can be disabled at the control van, thereby simulating loss of Vega. Upon simulating loss of Vega, the rudder deflection, altitude command, and elevator command produced by the on-board program are recorded.

14 This test is designed to check the jammer installed for the particular mission (narrow-band, or barrage). Initially, the jammer frequency is set from the control van to the particular mission frequency. The frequency is accurately set by monitoring the radiated signal (leakage radiation) on the control van receiver. At this time, the frequency command dial setting is recorded. The RF power is then measured directly on an RF power meter for each power setting (5, 10, and 25 watts) at which time the telemetry indication is recorded. The VSWR telemetry is only checked by removing the antenna and substituting a

dummy load of the proper value to produce the desired VSWR (for example, a 25 Ω load is used to produce a VSWR of 2:1). At this time the telemetry indication is recorded.

15 This test is designed to check the operation of the extendable antenna and the associated telemetry channel. The RPV is raised via a pulley arrangement so as to permit the extension of the antenna. The antenna is extended to specific lengths as verified by direct measurement, at which time the command setting and telemetry indication is recorded.

At the conclusion of these tests, if the results were deemed satisfactory the RPV is ready for flight. The RPV is then installed on the truck-top launcher and moved to the flight line. Approximately 15 minutes before scheduled lift-off, the RPV engine is started and its operation (idle RPM, maximum RPM, acceleration characteristics, etc.) is checked. Upon assuring satisfactory operation, the on-board alternator is activated by flashing the field from the GPU (the previous engine tests were conducted using the Kraft fail-safe battery). The operation of the alternator is verified at the GPU at which time the RPV avionics is turned on. The launch truck is then moved to the end of the runway at which time a range check of the control links is performed using both Vega and Kraft (the Kraft link is checked at both power levels, i.e., the intrinsic power of the self-contained Kraft transmitter and the 5 watts obtained by external amplification). The test consists of operating the flight controls (rudder, elevator and throttle) which are verified by the launch crew. Upon verification of the control links the RPV is cleared for launch at which time the launcher safety pins and the arresting devices (launcher and α flag) are removed. The control van is then checked for launch readiness (Vega plotter aligned and activated, telemetry recorders started, etc.) at which time the pilot is alerted that the RPV is ready to launch (the prelaunch check list is shown in figure 21). The pilot then commands maximum throttle and, if verified by the launch crew, the launch is commenced. The launch truck is accelerated until the lift light comes on at which time the RPV is released via the hand mechanism (the launch crew has the prerogative of aborting the mission during the run-up of the launch truck if anything appears amiss). As mentioned, a total of seven flights was made. A description of each flight follows.

<u>Flight Test No. 1, E-45</u>—The first flight occurred on 9 November 1976, utilizing the E-45 equipped with the barrage jammer and extendable antenna. Lift-off was at 1040 hours under good weather conditions and light winds. The takeoff was under Vega manual control, which was maintained as the pilot

Kraft Pwr. Amp. Range Check	Kraft Ant. Range Check	Vega Range Check	Pull 3 Launcher Arrest Pins	Release α Flag	Remove Bungees	Turn ON Ant. Reel Switch	Start T.M. Recorder	Start Flight Timer	Static RPM	Unloaded RPM	Vega Plotter Ready	Jammer On (End of Runway)	Time of Day	Date
√	√	√	√	√	√	N/A	√	√	6900	7800	√	√	1355	E-45 11-22
√	√	√	√	√	√	N/A	√	√	7100	7800	√	√	0937	E-45 11-23
									Wing N.E. 4 Kt					

Figure 21. Prelaunch Check List

circled the field while trimming the aircraft and gaining altitude. At an altitude of 1000 feet, control of the RPV was switched from manual to autopilot one loop at a time; i.e., the elevator control was switched first, then the throttle loop, and last the heading loop. The elevator and throttle autopilot control functioned well; however, the heading loop had minimal response, i.e., the turn rate was very slow. At that time it was decided to conduct the remainder of the flight under manual heading control, maintaining the elevator and throttle in autopilot. The command was then given to extend the antenna, while the RPV was under visual observation. The antenna was deployed to the maximum extension (108 inches) and appeared to maintain a good deflection angle with little lateral motion, although constant observation was impossible due to the altitude and range of the RPV. After several minutes of flying with the antenna fully extended, the antenna was retracted to 50 inches and the jammer was turned on. The jamming signal was immediately observed on the spectrum analyzer display in the control van. After several minutes of jamming, the jam signal disappeared from the analyzer, although the TM data from the RPV did not indicate any malfunction. Several seconds later the pilot indicated that the RPV was slowly losing altitude. This was then confirmed by the altitude telemetry, although the engine RPM was at the maximum. The loss of altitude persisted for several more seconds, at which time the pilot reverted to manual control and landed the RPV. Subsequent inspection of the aircraft disclosed little damage; however, the antenna weight was gone and the upper wing was marked as though by a whipping wire. It was concluded that the propeller had been nicked by the antenna, causing the loss of power; the exact manner could not be determined. It was further determined to install a propeller guard between the antenna and the propeller to prevent damage on the succeeding flight, and to increase the rudder deflection so as to improve autopilot operation of the heading loop.

Flight Test No. 2, E-45—The second flight occurred on 11 November 1976, again utilizing the E-45 equipped with the barrage jammer, extendable antenna, and the newly installed propeller guard. Lift-off was at 0900 hours under an overcast sky with winds of 10 to 13 knots. The takeoff was again under Vega manual control, which was maintained until an altitude of 1000 feet was attained. The control of the RPV was then transferred from manual control to autopilot. The heading control was improved from the previous flight; however, the turn rate was marginal, permitting the RPV to travel beyond the range of manual control. As the flight was not cleared for down-range operation, it was again decided to conduct the remainder of the flight under manual heading, maintaining the elevator and throttle control in autopilot. At this time the antenna was deployed to 50 inches; however, visual observation was not possible due to the overcast conditions. The jammer was then commanded on, which was confirmed by the appearance of the jam signal on the spectrum analyzer. The jammer remained on for approximately 30 seconds and again disappeared. The RPV again began to lose altitude, although at a very slow rate, and the pilot reverted to manual and landed.

Upon inspection it was discovered that the antenna weight was again missing; some antenna wire was found wrapped around the propeller guard, and an indentation with paint marks of the same color as the antenna weight was visible on the top of the wing. The conclusion as to the loss of power was again laid to antenna wire nicking the propeller. The manner in which the wire reached the propeller is unknown. However, the following speculations were reached:

a. The antenna weight went behind the propeller guard as it deployed.

b. The propeller guard was ineffective (the guard was of marginal size, slightly less than the diameter of the propeller).

c. The antenna wire went slack due to g forces and was blown into the propeller.

Flight Test No. 3, E-100—The third flight occurred on 18 November 1976, utilizing the E-100 equipped with the spot jammer and extendable antenna. Lift-off was at 0900 hours under good weather conditions and light winds. The takeoff was under Vega manual control. Upon takeoff, the RPV veered left and started to dive. The pilot immediately recovered to straight flight; however, the rate of climb was extremely poor. The pilot was forced to turn shortly after launch (due to the location of a restricted air space) and lost altitude in the turn. The pilot continued to circle the field in an effort to gain altitude. At the end of the second orbit, the safety officer ordered the plane to be landed.

Due to the extremely low altitude (approximately 50 feet which had been a struggle to attain), the pilot could not align the aircraft for a normal approach. The aircraft landed approximately 10 feet short of the east/west runway on the north side and bounced onto the edge of the runway. Upon inspection of the aircraft, it was discovered that although the damage to the aircraft was substantial, it was repairable.

The post mortem investigation into the flight of the E-100 was directed toward two main areas: the calculated engine power required to fly, and the actual power produced by the engine during the flight.

The required horsepower is based on theoretical calculations related to the aerodynamics of the RPV. The calculations were based on several assumptions such as drag coefficient based on a form drag of .050, a propeller efficiency of 65%, a wing efficiency of 80%, a linear lift coefficient versus angle of attack, etc. (see Figure 22). Assuming the drag coefficient used was a realistic number, it could be greatly affected by the trim of the aircraft. As the E-100 was somewhat altered (the engine was raised which thus changed the thrust line) since the maiden flight, the precise balance was not known at the time of flight.

Therefore, the horsepower calculations have an uncertainty related to the effect on wing efficiency caused by the dihedral and gull extensions, drag coefficient, possible effect on drag coefficient due to trim, propeller efficiency, and, at the low end of the horsepower curve, nonlinearity of the lift coefficient.

The horsepower produced by the E-100 engine during the prelaunch static run-up was determined to be 3.4 hp. This was accomplished by measuring the hp required to turn the E-100 propeller at several specific static RPM's (as determined from the flight log). The propeller hp vs. rpm curve was then fitted to the hp vs. rpm curve supplied by the engine manufacturer (it was assumed that although, the maximum power may not be valid, the shape of the curve remained the same). Based on this information, the maximum engine power during the static run-up was extrapolated to be 4.2 hp at approximately 7700 rpm.

As the available engine power appears to be adequate (based on the theoretical calculations), the propeller pitch was explored as a possible problem area, for the maximum air speed in level flight is limited by the combination of the pitch and rpm of the propeller. The known flight data is limited to the engine rpm (static, maximum unloaded at lift-off and during flight) and launch velocity. The engine rpm was 5900 static prelaunch, 7200 maximum unloaded,

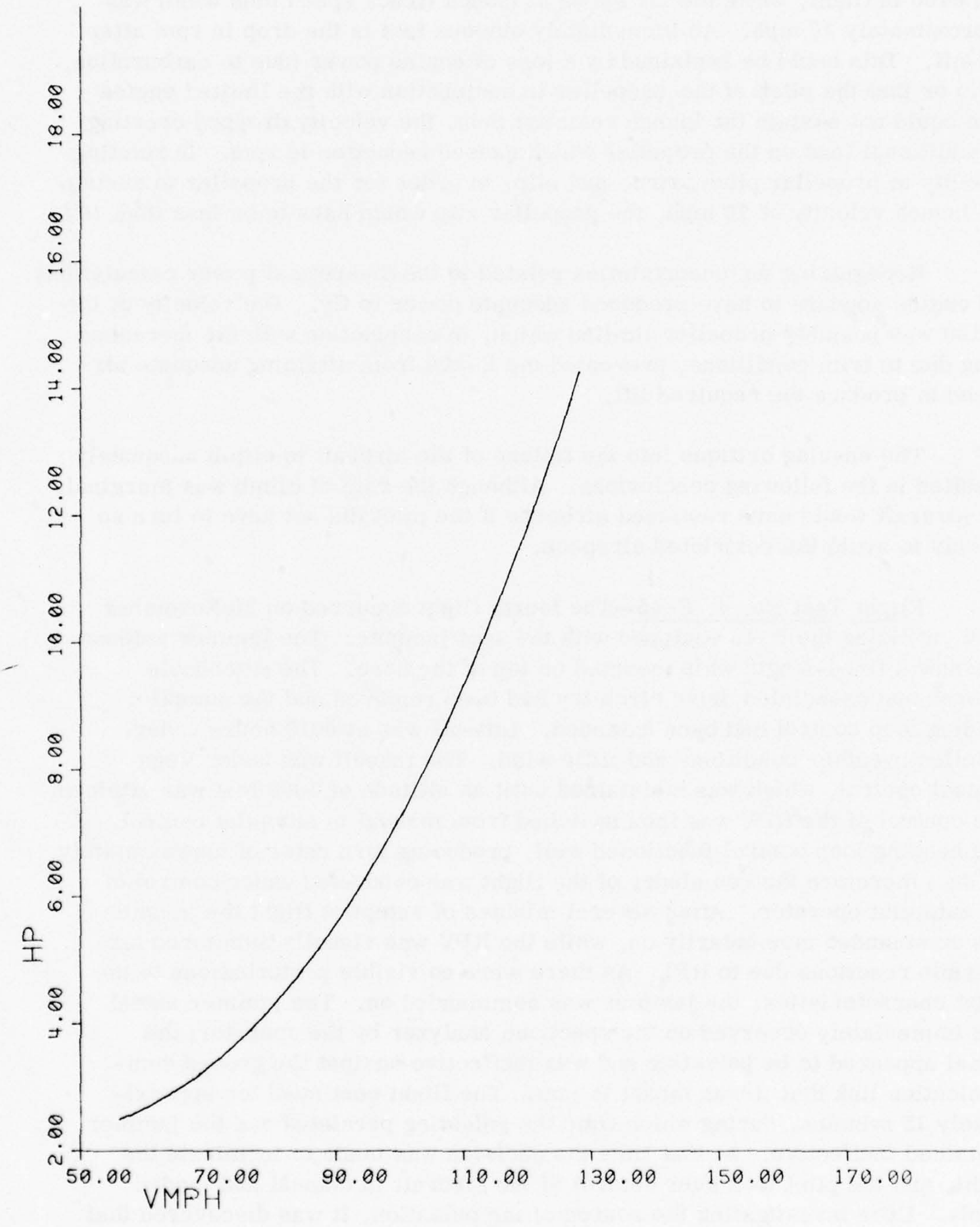

Figure 22. Calculated E-100 Power Requirements

and 6400 in flight, while the air speed at launch (truck speed plus wind) was approximately 70 mph. An immediately obvious fact is the drop in rpm after lift-off. This could be explained by a loss of engine power (due to carburetion, etc.) or that the pitch of the propeller in conjunction with the limited engine rpm could not sustain the launch velocity; thus, the velocity dropped creating an additional load on the propeller which caused reduction in rpm. In relating velocity to propeller pitch, rpm, and slip, in order for the propeller to sustain the launch velocity of 70 mph, the propeller slip would have to be less than 10%.

Recognizing the uncertainties related to the theoretical power calculations, the engine appears to have produced adequate power to fly. The velocity of the E-100 was possibly propeller limited which, in conjunction with the increased drag due to trim conditions, prevented the E-100 from attaining adequate air-speed to produce the required lift.

The ensuing critique into the failure of the aircraft to climb adequately resulted in the following conclusions. Although the rate of climb was marginal, the aircraft would have remained airborne if the pilot did not have to turn so quickly to avoid the restricted airspace.

Flight Test No. 4, E-45—The fourth flight occurred on 20 November 1976, utilizing the E-45 equipped with the spot jammer. The jammer antenna was now a fixed-length whip mounted on top of the nose. The extendable antenna and associated drive circuitry had been removed and the autopilot heading loop control had been extended. Lift-off was at 0915 hours under excellent weather conditions and little wind. The takeoff was under Vega manual control, which was maintained until an altitude of 1000 feet was attained. The control of the RPV was then switched from manual to autopilot control. The heading loop control functioned well, producing turn rates of approximately 4°/sec; therefore the remainder of the flight was conducted under control of the autopilot operator. After several minutes of autopilot flight the jammer was commanded momentarily on, while the RPV was visually monitored for possible reactions due to RFI. As there were no visible perturbations to the flight characteristics, the jammer was commanded on. The jammer signal was immediately observed on the spectrum analyzer by the operator; the signal appeared to be pulsating and was ineffective against the ground communication link that it was meant to jam. The flight continued for approximately 15 minutes, during which time the pulsating persisted and the jammer remained ineffective. At that time the decision was made to terminate the flight, and the pilot took over control of the aircraft in manual and landed safely. Upon investigating the source of the pulsation, it was discovered that the jam signal was overloading the Kraft receiver (due to the high power level and collocation of the antennas), creating a signal indicating Kraft takeover which shut down the jammer. Therefore, an oscillatory condition was established turning the jammer on and off. An analysis of the situation showed that the problem could be eliminated by two separate approaches: (1) insert a bandpass filter between the Kraft receiver and its antenna, and (2) prevent the Kraft loop from shutting down the jammer. As a bandpass filter was not available, and the equipment to design and fabricate one was not available in the field, the latter course was taken. However, to prevent the jammer from taking control of the aircraft via the Kraft loop, the Kraft autopilot takeover circuitry was redesigned so as to be disabled when the jammer was on.

Flight Test No. 5, E-45—The fifth flight occurred on 22 November 1976, utilizing the E-45 equipped with the spot jammer (set for 10 watt operation and modified to eliminate Kraft shutdown of the jammer) and whip antenna. Lift-off was at 1330 hours under good weather conditions with little wind. The takeoff was under Vega manual control, which was maintained until an altitude of 1000 feet was attained. During this time some Vega dropout occurred although the pilot did not report any loss of control. At this time the Vega antenna mounted on top of the control van was being used, whereas in the previous flights the antenna on top of the Vega van had been used. The Vega dropout persisted at which time the decision was made to transfer from the control van antenna to the Vega van antenna. The pilot was instructed to transfer to the Kraft control system at which time the antenna transfer was made. Upon making the transfer (a period of 4-5 minutes) control of the RPV was returned to the Vega system. The Vega system again experienced dropouts for the first several minutes (thus indicating the transfer of antennas did not cure the problem). However, shortly thereafter the dropouts stopped and a steady lock was maintained for the remainder of the flight. The control of the aircraft was then switched to autopilot which was maintained for the duration of the flight. The jammer was then commanded on, at which time normal operation was confirmed by the operator. The jammer was reported to be effective against the ground communication link; thus, the flight was continued for approximately 30 minutes while the operator, in conjunction with the ASA officer in charge, conducted several tests to further affirm jamming effectiveness. After a flight time of approximately 60 minutes, the tests were concluded and the aircraft landed safely in the manual mode. The path of this flight is shown in Figure 23.

Flight Test No. 6, E-45—The sixth flight occurred on 23 November 1976, utilizing the E-45 equipped with the spot jammer (set to operate at a fixed frequency of 45.15 MHz at a 10-watt output level) and a whip antenna. Lift-off occurred at 0900 hours under good weather conditions and a light wind. The

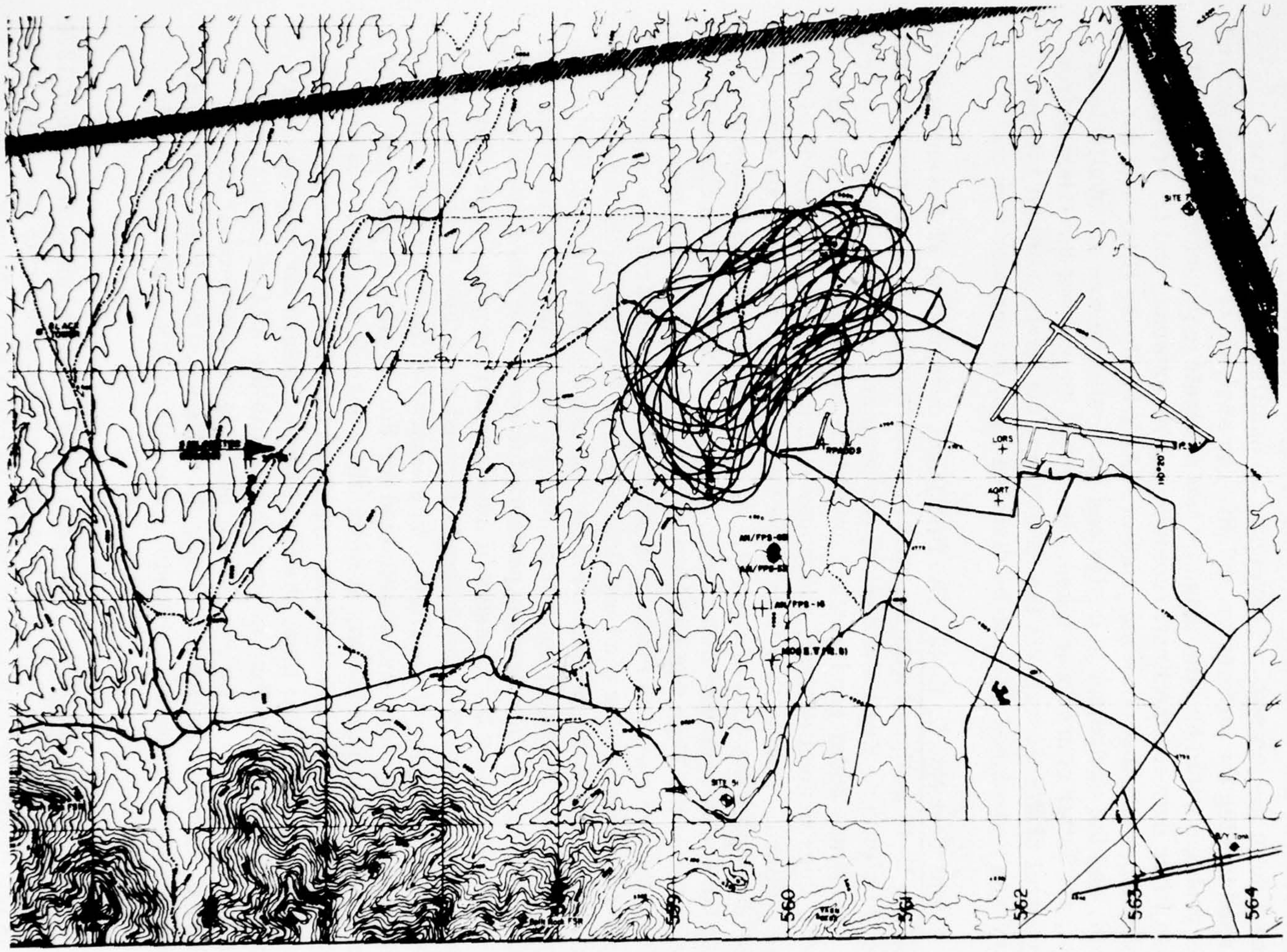

Figure 23. Flight No. 6, Station 12 (Fort Huachuca)

takeoff was under Vega manual control, which was maintained as the pilot circled the field in order to gain altitude. During the third orbit of the field the engine quit, forcing the pilot to make a "dead stick landing." The plane landed safely without any damage. The ensuing checkout to determine the cause of engine failure did not disclose any apparent malfunction. Several attempts were made to run the engine, at which time the engine would start when manually choked, but would stall when the choke was removed. This suggested blockage of the fuel line; therefore, the carburetor was cleaned and new reed valves were installed. The engine was subsequently restarted and the necessary carburetor adjustments were made; then the engine ran well.

Flight Test No. 7, E-45—The seventh flight occurred on the afternoon of 23 November 1976 after the engine was worked on, following the engine failure during the morning flight. Lift-off occurred at 1500 hours under good weather conditions. The takeoff was under Vega manual control which was maintained as the pilot circled to attain altitude. At an altitude of 1200 feet the pilot was making a wide turn to set up for transfer to autopilot control. At this time the Vega control link indicated loss of lock. The Vega operator reacquired lock several times, during which times the pilot indicated momentary loss of control. The intermittent condition persisted for approximately 30 seconds and the pilot lost control completely. The pilot then transferred to the Kraft control system; however, by that time the aircraft was in a right-turn, nose-down attitude, at full rpm. The pilot was unable to acquire any indication of control of the aircraft via the Kraft link, and the plane continued in the dive until it crashed. The RPV crashed approximately 1-1/2 kilometer north of the field and was totally demolished.

The ensuing critique did not produce any concrete evidence as to the cause of the crash. However, the following significant facts were disclosed:

a. The Vega dropouts prior to the crash would cause loss of control. However, if the Vega problem was simply loss of uplink, the system should have reverted to a circle and climb mode 3 seconds after a loss of signal. As there was no indication of the advent of circle and climb, there is no conclusive evidence of a failure in the Vega link.

b. Control of the aircraft could not be regained when the uplink was transferred from Vega to Kraft, thus indicating the Kraft system was not functional.

The two facts stated above led to the following conclusions:

a. The loss of Vega control could have been caused by numerous malfunctions; however the simultaneous loss of the Kraft control would limit the failure to circuitry common to both modes, namely the switching circuitry which transfers control from Vega to Kraft.

b. The inability of the pilot to gain control of the RPV via the Kraft link could have been caused by a failure of the circuitry common to both Kraft and Vega, or the Kraft link could have been jammed by an external source of RFI resulting in the transfer of control from the Vega link, producing erroneous commands to the avionics and blocking the Kraft receiver to the normal uplink commands.

SUMMARY OF JAMMING EFFECTIVENESS

The effectiveness of the airborne jammer against a ground communication link was judged by the ability of radio operators to understand voice communication messages transmitted in the presence of the jamming signal. The test was implemented by establishing a good quality two-way communication link between two or more stations in close proximity to the flight path of the RPV prior to operating the jammer. Seven RPV flights were made; however, only two (No. 1 and No. 5) produced any significant data. Flight test No. 1 consisted of the E-45 equipped with the barrage jammer. The communication link consisted of two stations operating at 45.15 MHz. In addition, the communications were being monitored with a PRC 77 located at the launch site. Upon activating the jammer, the jammer signal could be heard on the PRC 77; however the communication link was not affected. Test flight No. 5 was conducted with the spot jammer on board. The jammer was set for operation at a fixed frequency of 45.15 MHz. At the onset of the jammer operation, station A was transmitting and station B was receiving. Immediately upon activating the jammer, the communication between the two stations was totally obliterated, with only the noise of the jammer heard. The jamming effectiveness continued for several orbits of the flight path. Communication between stations A and B could be attained only when the jammer was turned off. Under these conditions the RPV had a decided range advantage over station A. Therefore in order to obtain data under more difficult conditions, the direction of communication was reversed, i.e., station B transmitted to station A. Under these conditions, the jammer and station B were equally distant from station A. The communication between the two stations was again completely disrupted when the jammer was turned on. The jamming continued for approximately 15 minutes (several orbits of the flight path), during which time communication could be established only when the jammer was turned off.

CONCLUDING REMARKS

The possible interference between the Vega control link and the FPS-16 bears further investigation.

The FPS-16 is a tracking radar used for range safety control (which includes beacon tracking capability) and can operate in conjunction with the Vega beacon contained on the RPV. The FPS-16 and the Vega control system operated at the same frequencies throughout the period of the jammer flight test: 5.825 GHz uplink and 5.725 GHz downlink. The Vega airborne system has two modes of operation: track and control. The track mode of operation operates with a two-pulse code with 3-μsecond spacing while the control mode of operation utilizes a 5 μsecond spacing. Either code spacing will trigger the airborne beacon; however, only the latter will activate the control decoding circuitry. Thus, the Vega system can be simultaneously tracked and controlled without interference, unless the two signals arrive at the same time; for example, if the legitimate signal arrived with the 5 μsecond spacing (thereby activating the decoder) and was immediately followed by the tracking signal, the decoder would interpret the track pulse as pulse position modulation and, thus, produce erroneous data. In addition, if the track signal triggered the beacon just prior to the arrival of the control signal, the signal transmitted by the beacon in reply would block the receiver to the receptions of the control signal. If the two systems were synchronized to one another, the phase relation between the two pulse trains could be adjusted so that overlap would never occur and, thus, there would be no interference. However, the two systems were not synchronized; therefore, the pulse train will overlap for a period of time dependent on the frequency difference between the two pulse rates. In the worst case, if the two frequencies were identical, if pulse train overlap occurred, it would persist continuously and would thus disrupt the control link.

The only mission during which the FPS-16 was scheduled to track the RPV was flight No. 4 flown on 20 November. However, the FPS-16 was operating on independent missions during other RPV flights. Initially the FPS-16 was using 5 μsecond pulse spacing for those missions. It was inadvertently discovered by Melpar that while using the Vega system to perform ground testing of the RPV the FPS-16 was having interference problems. Subsequent interplay between the two operations disclosed that the Vega system was causing the FPS-16 interference. In order to avoid this source of interference during subsequent missions the FPS-16 changed the pulse code spacing from 5 μseconds to 7 μseconds. Although this change would prevent the FPS-16 from triggering the Vega beacon on-board the RPV, it did not prevent the possible interference due to pulse train overlap.

The problem of pulse train overlap would certainly be a problem during a mission in which the FPS-16 is tracking the RPV. It would seem that the probability of occurrence would lessen during RPV flights in which the FPS-16 was operating independently, as the RPV would have to be in the antenna beam of the FPS-16. This may not be the case, however, due to the extremely high RF power capability of the FPS-16 (1 megawatt) and the close proximity of the RPV site (1.5 kM). The free space transmission loss over a distance of 2 kilometers at a frequency of 6 GHz is 115 dB. The FPS-16 transmitted power of +90 dBm and the Vega beacon receiver's sensitivity of -60 dBm will permit operation over a total path loss of 150 dB. Therefore, if the back radiation of the FPS-16 is greater than -35 dB, the RPV would be continuously interrogated by the FPS-16.

A second approach to avoiding the potential RFI problem is to change the operating frequency of either the Vega system or the FPS-16. The frequency selectivity of the Vega airborne beacon does not appear adequate to prevent the FPS-16 from getting into the receiver however; therefore, an additional external RF filter would be required.

It is recommended that the area of RFI between the Vega system and FPS-16 be investigated prior to any future RPV operations in which both systems are employed.

APPENDIX A

E-45 GROUP WEIGHT STATEMENT

MIL-STD-1374 PART I

Name E-45

Date

Page 1 of 5

Model E-45

Report

GROUP WEIGHT STATEMENT

AIRCRAFT

(INCLUDING ROTORCRAFT)

ESTIMATED - CALCULATED - ACTUAL

(Cross Out Those Not Applicable)

CONTRACT NO. DAAJ02-76-C-0018

AIRCRAFT, GOVERNMENT NO.

AIRCRAFT, CONTRACTOR NO. 6034

MANUFACTURED BY E-SYSTEMS

		MAIN	AUX
ENGINE	MANUFACTURED BY O&R		
	MODEL O&R20A		
	NO. 001		
	TYPE 2.2 HP 1 cylinder 2 Cycle		

PAGES REMOVED	PAGE NO.

MIL-STD-1374 PART I

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

Name ______

Model E45

Date ______

Report ______

1	WING GROUP						6.5 LBS
2	BASIC STRUCTURE - CENTER SECTION					3.9	
3	- INTERMEDIATE PANEL						
4	- OUTER PANEL (2)					2.6	
5	- GLOVE					–	
6	SECONDARY STRUCTURE (Incl. Wing Fold Weight. Lbs.)					–	
7	AILERONS (Incl. Balance Weight Lbs.)					–	
8	FLAPS - TRAILING EDGE					–	
9	- LEADING EDGE					–	
10	SLATS					–	
11	SPOILERS					–	
12						–	
13					Total	6.5	
14	ROTOR GROUP						–
15	BLADE ASSEMBLY					–	
16	HUB & HINGE (Incl. Blade Fold Weight Lbs.)					–	
17						–	
18						–	
19	TAIL GROUP						1.2
20	BASIC & SECONDARY STRUCT. - STABILIZER					1.2	
21	- FIN (Incl. Dorsal)					–	
22	VENTRAL					–	
23	ELEVATOR (Incl. Balance Weight Lbs.)					–	
24	RUDDERS (Incl. Balance Weight Lbs.)					–	
25	TAIL ROTOR - BLADES					–	
26	- HUB & HINGE					–	
27						–	
28	BODY GROUP						7.3
29	BASIC STRUCTURE - FUSELAGE or HULL					3.8	
30	- BOOMS 1 Fin & Rudders (2)					3.5	
31	SECONDARY STRUCTURE - FUSELAGE or HULL					–	
32	- BOOMS					–	
33	- SPEEDBRAKES					–	
34	- DOORS, RAMPS, PANELS, & MISC.					–	
35						–	
36						–	
37	ALIGHTING GEAR GROUP (Type: Skid)						1.2
38	LOCATION	Running Gear*	Arrest Gear*	Structure	Controls		
39	Full Length of Fuselage			1.2		1.2	
40						–	
41						–	
42						–	
43							
44							
45	ENGINE SECTION or NACELLE GROUP						2.0
46	BODY - INTERNAL					2.0	
47	- EXTERNAL					–	
48	WING - INBOARD					–	
49	- OUTBOARD					–	
50						–	
51						–	
52	AIR INDUCTION SYSTEM					–	
53	DOORS, PANELS, & MISC.					–	
54						–	
55						–	
56						–	
57	TOTAL STRUCTURE (To Be Brought Forward)						18.2

*Change to Floats & Struts for Water Type Gear.

MIL-STD-1374 PART I

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

Name E-45
Date

Page 3 of 5
Model E-45
Report

1	PROPULSION GROUP	Auxiliary		Main		6.9
2	ENGINE INSTALLATION		–		3.8	
3			–			
4	ACCESSORY GEAR BOXES & DRIVE		–		–	
5			–		1.5	
6	EXHAUST SYSTEM		–		–	
7	ENGINE COOLING		–		–	
8	WATER INJECTION		–		–	
9	ENGINE CONTROL		–		–	
10	STARTING SYSTEM		–		–	
11	PROPELLER INSTALLATION		–		1.6	
12	SMOKE ABATEMENT		–		–	
13	LUBRICATING SYSTEM		–		–	
14	FUEL SYSTEM		–		–	
15	TANKS - PROTECTED			–		
16	- UNPROTECTED			–		
17	PLUMBING, etc.			–		
18	DRIVE SYSTEM				–	
19	GEAR BOXES, LUB SY & ROTOR BRK			–		
20	TRANSMISSION DRIVE			–		
21	ROTOR SHAFTS			–		
22	JET DRIVE				–	
23				–	–	
24	FLIGHT CONTROLS GROUP					4.2
25	COCKPIT CONTROLS (Autopilot Lbs.)				3.9	
26	SYSTEMS CONTROLS Servos				.3	
27						
28						
29	AUXILIARY POWER PLANT GROUP Batteries, Jammer					4.7
30	INSTRUMENTS GROUP					–
31	HYDRAULIC & PNEUMATIC GROUP					–
32						
33	ELECTRICAL GROUP					–
34						
35	AVIONICS GROUP					–
36	EQUIPMENT				–	
37	INSTALLATION				–	
38					–	
39	ARMAMENT GROUP (Incl. Passive Prot. Lbs.)					–
40	FURNISHINGS & EQUIPMENT GROUP					–
41	ACCOMMODATION FOR PERSONNEL				–	
42	MISCELLANEOUS EQUIPMENT				–	
43	FURNISHINGS				–	
44	EMERGENCY EQUIPMENT				–	
45						
46	AIR CONDITIONING GROUP					–
47	ANTI - ICING GROUP					–
48						–
49	PHOTOGRAPHIC GROUP					–
50						–
51	LOAD & HANDLING GROUP					–
52	AIRCRAFT HANDLING				–	
53	LOAD HANDLING				–	
54					–	
55	MANUFACTURING VARIATION					–
56	TOTAL FROM PAGE 2					18.2
57	WEIGHT EMPTY					34.0

GROUP WEIGHT STATEMENT
USEFUL LOAD AND GROSS WEIGHT

Model E-45
Report ____

Name ____
Date ____

1	LOAD CONDITION								–
2									–
3	CREW (No.)								–
4	PASSENGERS (No.)								–
5	FUEL		Location	Type	Lbs.				–
6	UNUSABLE		Center	Gas/oil	6.5				6.5
7	INTERNAL								–
8									–
9									–
10									–
11	EXTERNAL								–
12									–
13									–
14	OIL								–
15	TRAPPED								–
16	ENGINE								–
17									–
18	FUEL TANKS (Location)								–
19	WATER INJECTION FLUID (Gals.)								–
20									–
21	BAGGAGE								–
22	CARGO								–
23									
24	GUN INSTALLATIONS								
25	GUNS	Location	Fix. or Flex	Quantity	Caliber				
26									
27									
28	AMMO								
29									
30									
31	SUPP'TS								
32	WEAPONS INSTALL. (Incl. Submarine Detection Expendables)								
33									
34	Narrow Band Jammer/Antenna								9.0
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									
46	EQUIPMENT								–
47									
48	SURVIVAL KITS & LIFE RAFTS								–
49									
50	OXYGEN								–
51									
52									
53									
54									
55	TOTAL USEFUL LOAD								15.5
56	WEIGHT EMPTY								34.0
57	GROSS WEIGHT								49.5

*If Removable and Specified as Useful Load

**List Stores, Missiles, Sonobuoys, etc. Followed by Racks, Launchers, Chutes, etc. Not Part of Weight Empty. List Identification, Location, and Quantity for All Items Shown Including Installation.

GROUP WEIGHT STATEMENT
DIMENSIONAL AND STRUCTURAL DATA

Name ____________

Model E-45

Date ____________

Report ____________

1	WING, ROTOR & TAIL GROUPS	SPAN OR RADIUS (FT.)	SPAN AT **** 25% CHORD	THEO. ROOT ** CHORD (IN.)	MAX. THICK ** ROOT CHORD (IN.)	THEO. TIP CHORD (IN.) **	MAX. THICK ** TIP CHORD (IN.)
2	WING	10.0					
3							
4	MAIN ROTOR (Blades/Rotor)						
5	TAIL ROTOR (Blades/Rotor)						
6	HORIZ. TAIL	2.0					
7	VERT. TAIL	1.4					
8							
9	AREAS - (Sq. Ft.)	Wing	MAIN ROTOR BLADE AREA	TAIL ROTOR BLADE AREA	Horiz. Tail	Vert. Tail	Dorsal
10	(Theo. for Wing & Rotor, All Others Exposed)	9.3			1.5	2.0	–
11		Speed Brks.	Flaps (L.E.)	Flaps (T.E.)	Slats	Spoilers	Ailerons
12	AREAS - (Sq. Ft.)	–	–	–	–	–	–
13	BODY & NACELLE GROUPS	Length (Ft.)	Depth (Ft.)	Width (Ft.)	WETTED AREA (SQ. FT.)	Vol. (Cu. Ft.)	VOL. PRESS. (CU. FT.)
* 14	FUSELAGE or HULL (Overall)	7.8					
15	BOOMS						
16	NACELLES						
17							
18							
19	ALIGHTING GEAR GROUP	Length - Oleo Ext		Oleo Travel		Length - Arrest Hook	
20		Axle to ℄ Trunnion		Ext. to Collapsed		Hook Trunnion to Pt.	
21	LOCATION						
22	DIMENSIONS (Inches) Skid	24.0"					
23							
24	PROPULSION GROUP						
25	ENGINES	S.L.S. THRUST IN LBS./ENG. WITH AFTERBURNER		S.L.S. THRUST IN LBS. ENG. WITHOUT AFTERBURNER		MAX. S.L.S. SHAFT H.P.	SHAFT R.P.M. AT MAX. H.P.
26	MAIN	–				–	2.2
27	AUXILIARY	–				–	
28	ROTOR DRIVE SYSTEM	Design H.P.	Input R.P.M.	OUTPUT R.P.M. AT ROTOR	INTER ROTOR R.P.M.	NUMBER GEAR BOXES	
29							
30		Protected		Unprotected		Integral	
31	FUEL - INTERNAL *** LOCATION	No. Tanks	Gallons	No. Tanks	Gallons	No. Tanks	Gallons
32	WING					1	1.0
33	FUSELAGE					–	–
34	- EXTERNAL ***						
35							
36	OIL					–	–
37	ELECTRICAL & LOAD & HANDLING GROUPS	QUAN. MAIN GENERATORS	GENERATOR OUTPUT D.C.	GENERATOR OUTPUT A.C.	Alt.	CARGO FLOOR AREA	
38					85 watts		
39							
40	STRUCTURAL DATA - CONDITION	BODY PLUS INT. CONTENT LBS.	EXTERNAL WT. ON BODY	FUEL IN WINGS (LBS.)		DESIGN GROSS WEIGHT	Ult. L.F.
41	FLIGHT - MANEUVER					50.0	
42	- GUST					50.0	
43	LANDING					50.0	
44							
45	MAX. GROSS WITH ZERO WING FUEL						43.5
46	CATAPULTING						–
47	LIMIT LANDING SINK SPEED (Ft./Sec.)						–
48	LIFT ASSUMED FOR LANDING DESIGN CONDITION (% W)						–
49	STALL SPD. - LDG. CONFIG. - POWER OFF						35K
50	PRESSURIZED CABIN - ULT. DESIGN PRESS. DIFFERENTIAL (FLIGHT P.S.I.)						–
51	ROTOR TIP SPD AT DESIGN LIMIT	R.P.M.	Power	Ft./Sec.	CONTRACTOR DESIGN FACTOR		–
52		–	–	–	–	–	–
53	% DESIGN LOAD	Wing		Rotor		Rotor	
54	DESIGN SPEED AT S.L. (Knots)	Level 44K		Dive			50.0
55	DESIGN SPD. AT OTHER ALTITUDES		Alt.		Alt.		
56							
57	DCPR WEIGHT (Airframe)						

*Nose to aft tip of fuselage (excluding equipment protuberances)
**Parallel to ℄ at ℄ Aircraft for Wing & Tail. Insert inches from ℄ Rotor for Rotors.
***Total Usable Capacity
****Insert inches from ℄ Rotor to Blade Attachment for Rotors.

APPENDIX B

E-100 GROUP WEIGHT STATEMENT

MIL-STD-1374 PART I

Name E-100

Date

Page 1 of 5

Model E-100

Report

GROUP WEIGHT STATEMENT

AIRCRAFT

(INCLUDING ROTORCRAFT)

ESTIMATED - CALCULATED - ACTUAL

(Cross Out Those Not Applicable)

CONTRACT NO. DAAJ02-76-C-0018

AIRCRAFT, GOVERNMENT NO.

AIRCRAFT, CONTRACTOR NO. 6034

MANUFACTURED BY E-SYSTEMS

		MAIN	AUX
ENGINE	MANUFACTURED BY Ross		
	MODEL Ross		
	NO.		
	TYPE 6.5 HP 4 Cylinder, 2 Cycle		

PAGES REMOVED	PAGE NO.

MIL-STD-1374 PART I

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

Page 2-5
Model E-100
Report

Name

Date

1	WING GROUP						17.2 Lbs
2	BASIC STRUCTURE - CENTER SECTION					7.2	
3	- INTERMEDIATE PANEL					–	
4	- OUTER PANEL (2)					10.0	
5	- GLOVE					–	
6	SECONDARY STRUCTURE (Incl. Wing Fold Weight Lbs.)					–	
7	AILERONS (Incl. Balance Weight Lbs.)					–	
8	FLAPS - TRAILING EDGE					–	
9	- LEADING EDGE					–	
10	SLATS					–	
11	SPOILERS					–	
12						–	
13						–	
14	ROTOR GROUP						–
15	BLADE ASSEMBLY					–	
16	HUB & HINGE (Incl. Blade Fold Weight Lbs.)					–	
17						–	
18						–	
19	TAIL GROUP						1.5
20	BASIC & SECONDARY STRUCT. - STABILIZER					1.5	
21	- FIN (Incl. Dorsal)					–	
22	VENTRAL					–	
23	ELEVATOR (Incl. Balance Weight Lbs.)					–	
24	RUDDERS (Incl. Balance Weight Lbs.)					–	
25	TAIL ROTOR - BLADES					–	
26	- HUB & HINGE					–	
27							
28	BODY GROUP						24.9
29	BASIC STRUCTURE - FUSELAGE or HULL					18.4	
30	- BOOMS					6.5	
31	SECONDARY STRUCTURE - FUSELAGE or HULL					–	
32	- BOOMS 1 Fin & Rudder (2 Each)					–	
33	- SPEEDBRAKES					–	
34	- DOORS, RAMPS, PANELS, & MISC.					–	
35							
36							
37	ALIGHTING GEAR GROUP (Type: Skid)						3.5
38	LOCATION	Running Gear*	Arrest Gear*	Structure	Controls		
39	Full Length of Fuselage			3.5		3.5	
40						–	
41						–	
42						–	
43							
44							
45	ENGINE SECTION or NACELLE GROUP						3.2
46	BODY - INTERNAL					2.2	
47	- EXTERNAL					1.0	
48	WING - INBOARD					–	
49	- OUTBOARD					–	
50						–	
51							
52	AIR INDUCTION SYSTEM					–	
53	DOORS, PANELS, & MISC.					–	
54							
55							
56							
57	TOTAL STRUCTURE (To Be Brought Forward)						50.3

*Change to Floats & Struts for Water Type Gear.

MIL-STD-1374 PART I

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

Page 3-5
Model E-100
Report

Name
Date

1	PROPULSION GROUP		Auxiliary		Main	20.0
2	ENGINE INSTALLATION		–		9.0	
3					–	
4	ACCESSORY GEAR BOXES & DRIVE				–	
5	Alternator				4.5	
6	EXHAUST SYSTEM				–	
7	ENGINE COOLING				–	
8	WATER INJECTION				–	
9	ENGINE CONTROL				–	
10	STARTING SYSTEM, Ignition Batt				2.6	
11	PROPELLER INSTALLATION				2.3	
12	SMOKE ABATEMENT				–	
13	LUBRICATING SYSTEM					
14	FUEL SYSTEM					
15	TANKS - PROTECTED			–		
16	- UNPROTECTED			1.6		
17	PLUMBING, etc.					
18	DRIVE SYSTEM				1.6	
19	GEAR BOXES, LUB SY & ROTOR BRK			–		
20	TRANSMISSION DRIVE			–		
21	ROTOR SHAFTS			–		
22	JET DRIVE				–	
23					–	
24	FLIGHT CONTROLS GROUP					5.6
25	COCKPIT CONTROLS (Autopilot Lbs.)				3.9	
26	SYSTEMS CONTROLS (Servos)				1.2	
27	Back-up Batt.				.5	
28						–
29	AUXILIARY POWER PLANT GROUP					–
30	INSTRUMENTS GROUP					–
31	HYDRAULIC & PNEUMATIC GROUP					–
32						
33	ELECTRICAL GROUP					–
34						
35	AVIONICS GROUP					3.5
36	EQUIPMENT Vega				3.3	
37	INSTALLATION Antenna				.2	
38					–	
39	ARMAMENT GROUP (incl. Passive Prot. Lbs.)					–
40	FURNISHINGS & EQUIPMENT GROUP					–
41	ACCOMMODATION FOR PERSONNEL					
42	MISCELLANEOUS EQUIPMENT					
43	FURNISHINGS					
44	EMERGENCY EQUIPMENT					
45						
46	AIR CONDITIONING GROUP					–
47	ANTI - ICING GROUP					–
48						–
49	PHOTOGRAPHIC GROUP					–
50						–
51	LOAD & HANDLING GROUP					–
52	AIRCRAFT HANDLING					
53	LOAD HANDLING					
54						
55	MANUFACTURING VARIATION					–
56	TOTAL FROM PAGE 2					50.3
57	WEIGHT EMPTY					79.4

MIL-STD-1374 PART I

GROUP WEIGHT STATEMENT
USEFUL LOAD AND GROSS WEIGHT

Name ______

Date ______

Model E-100

Report ______

1	LOAD CONDITION								
2									
3	CREW (No.)								
4	PASSENGERS (No.)								
5	FUEL	Location	Type	Gals.					
6	UNUSABLE								15.0
7	INTERNAL	C-wing	Glo-fuel	1.0					
8									
9									
10									
11	EXTERNAL	CG	Glo-fuel	1.1					
12									
13									
14	OIL								
15	TRAPPED								
16	ENGINE								
17									
18	FUEL TANKS (Location)								
19	WATER INJECTION FLUID (Gals.)								
20									
21	BAGGAGE								
22	CARGO								
23									
24	GUN INSTALLATIONS								
25	GUNS	Location	Fix. or Flex	Quantity	Caliber				
26									
27									
28	AMMO								
29									
30									
* 31	SUPP'TS								
** 32	WEAPONS INSTALL. (Incl. Submarine Detection Expendables)								
33									
34	Jammer/Antenna								15.0
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									
46	EQUIPMENT								
47									
48	SURVIVAL KITS & LIFE RAFTS								
49									
50	OXYGEN								
51									
52									
53									
54									
55	TOTAL USEFUL LOAD								30.0
56	WEIGHT EMPTY								79.4
57	GROSS WEIGHT								109.4

*If Removable and Specified as Useful Load

**List Stores, Missiles, Sonobuoys, etc. Followed by Racks, Launchers, Chutes, etc. Not Part of Weight Empty. List Identification, Location, and Quantity for All Items Shown Including Installation.

MIL-STD-1374 PART I

GROUP WEIGHT STATEMENT
DIMENSIONAL AND STRUCTURAL DATA

Name ______________

Model E-100

Date ______________

Report ______________

1	WING, ROTOR & TAIL GROUPS	SPAN OR RADIUS (FT.)	SPAN AT **** 25% CHORD	THEO. ROOT ** CHORD (IN.)	MAX. THICK ** ROOT CHORD (IN.)	THEO. TIP CHORD (IN.) **	MAX. THICK ** TIP CHORD (IN.)
2	WING	10.8					
3							
4	MAIN ROTOR (Blades/Rotor)	–					
5	TAIL ROTOR (Blades/Rotor)	–					
6	HORIZ. TAIL	2.2					
7	VERT. TAIL	1.6					
8							
9	AREAS - (Sq. Ft.)	Wing	MAIN ROTOR BLADE AREA	TAIL ROTOR BLADE AREA	Horiz. Tail	Vert. Tail	Dorsal
10	(Theo. for Wing & Rotor, All Others Exposed)	14.3	–	–	2.0	2.2	.6
11		Speed Brks.	Flaps (L.E.)	Flaps (T.E.)	Slots	Spoilers	Ailerons
12	AREAS - (Sq. Ft.)	–	–	–	–	–	1.0
13	BODY & NACELLE GROUPS	Length (Ft.)	Depth (Ft.)	Width (Ft.)	WETTED AREA SQ. FT.	Vol. (Cu. Ft.)	VOL. PRESS. (CU. FT.)
14	FUSELAGE or HULL						
15	BOOMS						
16	NACELLES						
17							
18							
19	ALIGHTING GEAR GROUP	Length - Oleo Ext.		Oleo Travel		Length - Arrest Hook	
20		Axle to ℄ Trunnion		Ext. to Collapsed		Hook Trunnion to Pt.	
21	LOCATION						
22	DIMENSIONS (Inches)						
23							
24	PROPULSION GROUP						
25	ENGINES	S.L.S. THRUST IN LBS./ENG. WITH AFTERBURNER		S.L.S. THRUST IN LBS./ENG. WITHOUT AFTERBURNER		MAX. S.L.S. SHAFT H.P.	SHAFT R.P.M. AT MAX. H.P.
26	MAIN						
27	AUXILIARY	—					
28	ROTOR DRIVE SYSTEM	Design H.P.	Input R.P.M.	OUTPUT R.P.M. AT ROTOR	INTER ROTOR R.P.M.	NUMBER GEAR BOXES	
29		—					
30		Protected		Unprotected		Integral	
31	FUEL - INTERNAL *** LOCATION	No. Tanks	Gallons	No. Tanks	Gallons	No. Tanks	Gallons
32	WING						
33	FUSELAGE						
34	- EXTERNAL ***						
35							
36	OIL						
37	ELECTRICAL & LOAD & HANDLING GROUPS	QUAN. MAIN GENERATORS	GENERATOR OUTPUT D.C.	GENERATOR OUTPUT A.C.		CARGO FLOOR AREA	
38							
39							
40	STRUCTURAL DATA - CONDITION	BODY PLUS INT. CONTENT (LBS.)	EXTERNAL WT. ON BODY	FUEL IN WINGS (LBS.)		DESIGN GROSS WEIGHT	Ult. L.F.
41	FLIGHT - MANEUVER					125.0	
42	- GUST					125.0	
43	LANDING					125.0	
44							
45	MAX. GROSS WITH ZERO WING FUEL					118.0	
46	CATAPULTING						
47	LIMIT LANDING SINK SPEED (Ft./Sec.)						
48	LIFT ASSUMED FOR LANDING DESIGN CONDITION (% W)						
49	STALL SPD. - LDG. CONFIG. - POWER OFF						42K
50	PRESSURIZED CABIN - ULT. DESIGN PRESS. DIFFERENTIAL - FLIGHT (P.S.I.)						
51	ROTOR TIP SPD AT DESIGN LIMIT	R.P.M.	Power	Ft./Sec.	CONTRACTOR DESIGN FACTOR	–	–
52		–	–	–	–	–	–
53	% DESIGN LOAD	Wing		Rotor		Rotor	
54	DESIGN SPEED AT S.L. (Knots)	Level 65K		Dive			
55	DESIGN SPD. AT OTHER ALTITUDES		Alt.		Alt.		
56					–		–
57	DCPR WEIGHT (Airframe)						

*Nose to aft tip of fuselage (excluding equipment protuberances)
**Parallel to ℄ of ℄ Aircraft for Wing & Tail. Insert inches from ℄ Rotor for Rotors.
***Total Usable Capacity
****Insert inches from ℄ Rotor to Blade Attachment for Rotor.

6761-77